THE FORCE-ORIENTED DEFENSE: AN EXPECTED-VALUE APPROACH

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THESIS

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ABSTRACT

As a first step in the testing of the feasibility of the FORCE-ORIENTED DEFENSE as a viable tactic for countering the large force imbalance in Western Europe, a small-unit, base-case scenario is quantitatively examined through the medium of a manual war game. A "Monte Carlo" type manual game was developed and used to refine model logic for a subsequent investigation with an expected-value manual game. This work generates the basis for a possible high resolution simulation of the FORCE-ORIENTED DEFENSE. To satisfy secondary objectives of the study, fractional kills were tabulated to determine first approximations of armor/antiarmor force exchange ratios and weapon system fractional loss rates. The specific scenario involved a reinforced mechanized infantry platoon ambushing the first echelon units of a tank-reinforced motorized rifle battalion.

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ABBREVIATIONS

AAA (or ADA)	Antiaircraft Artillery (or Air Defense Artillery)
AFV	Armored Fighting Vehicle
AP	Armor-Piercing
APC	Armored Personnel Carrier
AT	Antitank (or Antiarmor)
ATAP	Antitank, Auxiliary Powered
ATGM	Antitank Guided Missile
A2(M)	Tank-fired, Radio-guided, 152mm ATGM
Bde	Brigade
BLOS	Break Line-of-sight
BMP	Russian: Armored Infantry Combat Vehicle
Bn	Battalion
BRDM	Russian: Armored Reconnaissance Patrol Vehicle
Btry	Battery
C	Catastrophic Kill or -Kill Probability
CAA	Combined Arms Army
CDF	Cumulative Distribution Function
Co	Company
Coax MG	Coaxially-mounted machinegun
Div	Division
DS	Direct Support
Engr	Engineer
F	Firepower-Kill or -Kill Probability
FDC	Fire Direction Center
FEBA	Forward Edge of the Battle Area
FOD	Force-Oriented Defense
FPP	Firepower Potential
FS	Fin-stabilized
HAW	Heavy Antitank Assault Weapon
HE	High Explosive
HEAT	High Explosive Antitank
HEDP	High Explosive Dual Purpose
How	Howitzer
Hq	Headquarters
HVAPDS	High Velocity, Armor-Piercing, Discarding Sabot
Hv Tk/AG	Heavy Tank/Assault Gun
IR	Infra-red
K	Kill or Kill-Probability
LAW	Light Antitank Weapon
LMG	Light Machinegun
LOC	Line of Communications
LOS	Line-of-sight

M	Mobility-Kill or -Kill Probability
MAW	Medium Antitank Weapon
Mdm	Medium
Mech	Mechanized
Med	Medical
MG	Machinegun
MR (MRR, MRD)	Motorized Rifle (- Regiment, - Division)
MRL	Multiple Rocket Launcher
MUF	Joint occurrence of M or F
P(--)	Probability of -- occurring
Plat	Platoon
PT	Russian: Amphibious Tank
R	Range
Rd	Round of ammunition
Recon	Reconnaissance
Regt	Regiment
RN	Random Number
RR	Recoilless Rifle
RV	Random Variable
Scty	Security
Sec	Section or Second (as refers to time measure)
SP	Self-propelled
Sqd	Squad
Sqdn	Squadron
SSH	Single Shot Hit
STANO	Surveillance, Target Acquisition, Night Observation
SU	Russian: Self-propelled Mount
T	Time (a random variable)
Tgt	Target
Tk	Tank
Wpn	Weapon

I. BACKGROUND

A. INTRODUCTION

In light of the current imbalance of tactical ground forces in Europe between the NATO and Warsaw Pact forces, it has become imperative that maximum effective use be made of all available personnel and material to meet the apparent threat. Recent unclassified estimates vary as to the exact force levels and compositions, however, most agree that the Warsaw Pact armies have at least a three-to-one numerical superiority in main battle tanks with, in global terms, a definite margin of firepower superiority in conventional artillery [Refs. 1, 2, and 3].

Given any mutual and balanced force reduction, these NATO defense forces may find themselves in an even more critical situation: greatly over-extended defensive frontages and minimal reserve forces. Even with conservative current unclassified estimates, it is not unrealistic to assume that the combat power ratio facing NATO defensive forces along the border areas is definitely greater than seven-to-one in armored and mechanized (motorized) infantry units [Ref. 4].

B. CURRENT DEFENSIVE TACTICS

Assuming that such unfavorable combat power ratios will not appreciably improve in the near future, and assuming that widely extended defensive frontages may be the rule rather than the exception; it becomes readily apparent that the classical forms of defense: the AREA and MOBILE DEFENSE,

are infeasible. The reasons for this are that:

1. Successful employment of these tactics presupposes an availability of tactical units in sufficient numbers that a forward defense battalion will be required, under ideal circumstances, to hold no more than 5,000 meters of frontage through actual occupation and coverage of what is not occupied by fire [Ref. 5] and,

2. a successful mobile defense (in which controlled penetrations are allowed in order to inflict maximum casualties on the attacking enemy by employment of a brigade-sized counterattack) requires fixing forces and a large mobile reserve (counterattack force). But, with the quantity of superior-in-number, armor-heavy Warsaw Pact forces potentially employable in Western Europe, so many regimental-sized penetrations are possible that it would be virtually impossible to fix (hold) and counterattack all of them [Ref. 6].

Recent economy moves have been made to bolster the effectiveness of the forward defense units through the issuance of a multitude of the latest antitank/antiarmor (AT) weapons and surveillance, target acquisition and night observation (STANO) devices. These, in combination with the tactical capabilities of the attack and troop-lift helicopters, have partially offset the lack of ground combat units [Ref 7].

These technological advances, when employed in the area or mobile defense, hardly provide a significant marginal increase in effectiveness (when the intent is to hold terrain and defeat any force seeking to take the terrain from the defenders). The forward defenses would still be so thinly spread that any

sizable penetrations would effectively cause the defender to be turned out of position. One would also find the much-extended logistical system extremely vulnerable to destruction by large armored forces roaming freely deep in the defender's rear areas.

When the force being attacked is unable to effect one of the aforementioned classical forms of defense, it is obligated to conduct some form of retrograde operation to avoid decisive engagement and destruction in place. In the classical sense, the doctrinal form of retrograde operation of interest is the DELAY.

The delay, by definition, is "A type of defensive operation in which a force under pressure trades space for time while inflicting maximum punishment on the enemy without becoming decisively engaged" [Ref. 5]. The delaying units fire at the advancing enemy at the maximum effective ranges of the organic weapon systems, theoretically causing the attacker to deploy his units to maneuver on the defender. This, ideally, creates valuable time which the parent organization of the delaying forces needs to constitute its main defense further to the rear. To preclude piecemeal destruction of these delaying units, they seek to withdraw to subsequent delay positions before becoming decisively engaged. That is to say, before the attacker can bring such a volume of fire to bear on the delay position as to make the withdrawal virtually impossible. Here, freedom of action is essential to exploit any discovered situation which proves unfavorable to the enemy, to shift forces, or make maximum use of the available terrain [Ref. 5].

Technically speaking, therefore, the delay is keyed on the availability of suitable terrain (delay positions) from which long range observation and fire are afforded, and by which covered and concealed withdrawal routes are provided to the delaying units.

Incorporation of antitank guided missile systems augments the capabilities of mechanized infantry to destroy attacking armor. But it is readily apparent that current short and medium range antiarmor weapons could seldom, effectively, be brought to bear on armored targets, if the long range systems have already given away the general location of the delay position and enemy counterfires have been adjusted onto that position.

To wait until the enemy is within range of the shorter range systems is to risk attempting to engage deployed forces moving under cover of massive supporting fires and using covered and concealed attack routes, given immediately previous long range AT system fires have alerted the enemy.

This problem would, of course, be compounded by seeking to delay over defensive sector frontages initially greater than five times those doctrinally acceptable for the area or mobile defenses, <u>under ideal circumstances</u>.

In addition to force augmentation by antiarmor weapons and STANO devices, the search has been on to find a viable alternative tactic capable of effectively counteracting the potential threat, by optimal utilization of the defender's available resources.

C. THE PROPOSED ALTERNATIVE TACTIC

One such tactic, the FORCE-ORIENTED DEFENSE (FOD), has been proposed by the staff and faculty of the United States Infantry School, Fort Benning, Georgia: "The underlying principle of the force-oriented defense is that the defender offers a degree of resistence appropriate to the existing combat power ratio ... The objective is to create vulnerabilities that can be exploited to gain maximum returns with minimum expenditure of assets" [Ref. 6].

Unlike the delay, the FOD considers terrain only in the context that it determines where the enemy will move his units, and how it will facilitate destruction of those enemy units, through the inherent obstacles, observation and fields of fire, and cover and concealment it affords. The FOD also more readily accepts the possibility of some of the defender's units being bypassed (inadvertently or purposefully permitted), with subsequent attacks by these bypassed units on elements of the enemy force to the rear of the first or second attacking echelons. Such attacks would most likely come about as the bypassed units moved to re-establish contact with the remainder of their organizations, thus again seeking to position themselves ahead of the enemy's first echelon units [Ref. 7].

To test feasibility relative to current doctrine and tactics, it is necessary to examine in detail only those aspects which are peculiar to the FOD concept and have a major impact on discernible differences this concept may provide.

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interfacings these have with the more universally employed defensive tactics.

For example, in this study, long range ATGM engagements of armored targets were of interest only in the manner in which they bore on the effectiveness of mechanized infantry antiarmor ambushes. That is to say, ATGM's can be employed in relative isolation wherein the missiles are fired at maximum effective ranges, as soon as targets become available; or, they can be held until the targets have entered a preselected killing zone into which the maximum number of missiles may be fired in a surprise salvo. The significance here is that the second choice precludes piecemeal employment of long range systems which, in turn, can be reacted upon before medium and short range systems can be utilized. Note that this does not preclude a simultaneous employment of the long range systems elsewhere, under the first mode of employment. In fact, the formulators of the FOD recognized that, "Only our long-range antiarmor weapons, to include aerial antiarmor platforms, should be used in those areas which strongly favor massive and rapid armor thrusts, and in those which offer scant cover and concealment for the defender" [Ref. 6].

Conceptually, the FOD makes maximum use of small unit antiarmor ambushes. Such a tactic would thus employ the short and medium range antiarmor weapons in a manner which makes optimal use of their armor-killing capabilities. It should be recalled, however, that the FOD is not limited to such ambushes. These are simply techniques more or less

unique to the FOD (when speaking of such a large-scale application of such ambushes). The general principle of resistance appropriate to meet the existing combat power ratio may require defending from a built-up area (urban areas being major obstacles to armor) for a specified period of time for example.

The particular tactic of interest, for detailed study, was determined to be the small-unit antiarmor ambush. If, then, the FOD makes maximum use of and derives a major portion of its effect from such small-unit antiarmor ambushes, in order for the FOD to be a feasible alternative tactical concept, the following must be true:

1. The engagement exchange ratios and weapon attrition rates must be favorable to the defender.

2. The defender must be able to achieve a density of such ambushes between the point of initial enemy contact and the location of the final, determined defense, as to cut the combat power ratio down to within acceptable limits. (This is usually interpreted to mean less than three-to-one, attacker-to-defender.) Theoretically, then, with such a combat power ratio, the defender may undertake one of the more classical forms of defense. Inherent in this is the assumption that the requisite density of ambush positions, along the major identified enemy avenues of approach, are available. The actual determination of position availability was beyond the scope of this study.

A hypothetical situation will serve to illustrate the exchange ratio/position density problem: Suppose a mechanized

infantry division, with normal attachments from Corps, is faced by a combined arms army. Suppose, also, that the two forces are organized as shown in Table I. Note that the combat support units are listed together, this is for convenience only. The normal detachments/attachments, direct support and reinforcing missions as for a retrograde operation would be employed [Refs. 7 and 8].

Now suppose, from the point of passage of the corps covering force (normally an armored cavalry regiment) where first contact may be expected between the enemy force and the mechanized infantry division, the final defensive line established by the corps commander for the forward divisions is 100 kilometers to the rear. Assuming a width of sector of 45 to 60 kilometers for the division, one sees each of the two forward mechanized brigades having attrition areas approximately 20 to 30 kilometers wide and 100 kilometers deep.

To calculate the requisite density of antiarmor ambushes, some measure of relative combat power is necessary. A gross approximation of the relative combat power of a tactical organization is its firepower potention (FPP). It should be noted that this is not an attempt to, in any way, justify the FPP methodology. FPP scores were herein employed due to their simplistic nature, purely for purpose of illustration. Since exact values are not required for this illustration, it may be presumed that the aggregated FPP scores can be represented by the maximum possible scores attributable to a unit. This presupposes that each unit will be employed in an optimal fashion, to maximize its firepower potential.

TABLE I.

SAMPLE ORGANIZATION FOR COMBAT

BLUE-Mech Inf Division	Initial	Final	RED-Combined Arms Army	Initial
Attrition Forces: 1st Bde:	2 Mech Inf Bn 1 Mech Bn (-) 1 Tk Co (M60A2)	90% of 2 Mech Inf Bn	First Echelon: 11th MRD: (12th, 13th, & 14th MRD- same structure)	3 MR Regt 1 Tk Regt 1 Hvy Tk/AG Regt 1 Sapper Bn 1 Recon Bn 1 MRL Bn 2-152How Regt
2nd Bde:	2 Mech Inf Bn 1 Mech Inf Co 1 Tk Bn (-)	90% of 2 Mech Inf Bn		
Security/Attrition Forces:	1 Armd Cav Sqdn			
Reserve: 3rd Bde	4 Tk Bn (M60A1) 1 Mech Inf Bn	80% of 4 Tk Bn	Second Echelon: 5th Tk Div: (6th Tk Div- same structure)	3 Tk Regt 1 MR Regt 1 Hvy Tk/AG Regt 1 AAA Regt 1 MRL Bn 1 Recon Bn 1 Sapper Bn 2-152 How Regt
Combat Support:	1 Engr Bn 1 ADA Bn 2-155 How Bn 1 8in How Bn 1 175 Gun Bn	50% of Engr Co 50% of ADA Bn 1-155 How Bn 75% of 8in Bn 75% of 175 Bn		
On Order:	1 Aerial Weapons Co	50% of Aerial Weapons Co		
			Army Troops:	1 AAA Div 1 Arty Bde 1 MRL Regt 1 Recon Regt 1 AT Arty Bde
FPP Score:	30,400 + ADA	18,180 + 50%ADA		213,000

Combat Power Ratio- 213,000:30,400= 7:1, or greater.

Applying such a methodology to the hypothetical defender (BLUE) and attacker (RED), FPP scores may be drawn from the appropriate listings in Ref. 9. Example aggregate scores are reflected in Table I.

It is readily seen that any attempt to reach a combat power ratio less than 3:1, with BLUE having a supposed minimum acceptable FPP of 18,200 at the point of final defense, would require an attrition of more than 159,000 FPP points from RED. Arbitrarily, let it be assumed that 75,000 points must be attrited by small-unit antiarmor ambushes. If each ambush were to average an attrition of six tanks (two Red-type platoons) and three armored personnel carriers (equivalent, when loaded with troops, to one motorized rifle platoon), the loss to the Red force per engagement would be approximately 250 points. This, then, implies that 300 such ambushes need be conducted before the Red force has advanced 100 kilometers. With ambushes oriented only on identified avenues of approach through the sector (keying on the observed usage of these avenues by the enemy force), the Blue commander may be faced with the task of initiating an ambush every 20 square kilometers. A regimental avenue of approach five to eight kilometers wide would then have to be ambushed, on the average, every two to four kilometers along its potential 100 kilometer length.

If the terrain or forces available, given the assumptions leading to the required density, were not adequate, the tactic, as envisioned, would not be feasible. It becomes important, therefore, that estimates of force exchange ratios and weapon system attrition rates per engagement be determined. With

such information, the commander may determine the feasibility of employing this particular aspect (the antiarmor ambushes) of the FOD.

With the foregoing in mind, a methodology for deriving such exchange ratios and attrition rates is presented integral to this study.

D. PREVIOUS ANALYSES OF THE PROPOSED CONCEPT

To the knowledge of the author, as of the preparation of this study, the FOD has only been subjected to an exercising of the "JIFFY" manual wargame at Fort Leavenworth, Kansas, in 1971-1972, and periodic field simulations utilizing students from the Infantry Officer Advanced Course at the United States Army Infantry School, Fort Benning, Georgia.[1] Additionally, the FOD concept was sent to the other Army branch schools for staffing during its formulation phases.

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[1] NOTE: These field exercises are run under the auspices of the Defense Committee, Brigade and Battalion Operations Department, USAID, and involve pitting two groups of vehicular-mounted students against each other. One group acts as the attacking Warsaw Pact-type Red armored force, moving along a predetermined avenue of approach through the training area. The other group simulates a force composed largely of ATGM systems with a mission of conducting a Force Oriented Defense in the assigned sector. Besides providing the students experience in selecting ATGM firing positions and ambush killing zones, the exercises have shown that the assumed Warsaw Pact-type tactic of fast-moving column formations judgmentally results in more Red tank losses than the more cautious US rate. - Essence of conversation with LTC Joseph Keyes, Chairman, Defense Committee, BBOD, USAIS, Fort Benning, Georgia, 29 June 1973.

II. ANALYSIS OF THE PROPOSED TACTIC

A. A HIERARCHY OF MODELS

Prior to actually field testing a concept, some form of a relatively cost-effective analytical study is normally taken. Since the complexities of modeling a small-unit antiarmor ambush require more than a measure of effectiveness such as the rate of FEBA movement or tons of ammunition expended per day in support of troops in contact, one sees that a purely analytic formulation of this concept will yield no tractable closed-form solutions. This, then, leaves high resolution simulations. It was recognized that some significant changes might be required to model the FOD small-unit antiarmor ambushes by such high-resolution simulations as DYNTACS and CARMONETTE.

In light of the foregoing, a base-case scenario, with a set of realistic model-simplifying assumptions would act as a first cut at the modeling problem; acting as a guide to the simulation model formulators.

This study, then, has sought, through development and exercising of a manual war game, the derivation of both a base-case methodology and suggested model-simplifying assumptions. Although the model is quite simplified, it presents a means of considering, sequentially, the critical events and situations impacting on the battle outcome. These events and situations include, but are not restricted to: Composition of forces; formations and rates of movement; tactical plans and standard operating procedures; and, target detections, acquisitions and engagements.

To be of value, given the tactical situation and mission, such a model should provide, as outputs, exchange ratios of weapon systems or tactical organizations, weapon attrition (kill) rates per type engagement, end-of-engagement dispositions, and indications of whether or not a force appears to be employing its optimal tactics. (Such outputs were secondary objectives of this study.)

Realistic values for outputs, such as those enumerated above, are not necessarily to be expected from the proposed model in that the inputs employed were, in many cases, gross approximations of or extrapolations from known data. This is particularly the case as applies to Warsaw Pact-type weapon system characteristics, and characteristics of classified US antitank guided missile systems. (Although the foregoing smacks of lacking in mathematical rigor, the reader is reminded that the main purpose of modeling is taken to be the development of insight.) What is of use, therefore, is the methodology employed, providing the framework into which updated or classified versions of the data may be put and exercised.

Since exercising the manual war game, involving random number draws for determination of results at each step in each engagement, required a great deal of time, the obvious trends detected within the conflict simulation were extracted, linked with the hit/kill probabilities, target acquisition times, etc., and incorporated into an expected-value model. The expected-value model was, in turn, exercised to derive the exchange ratios, weapon attrition rates, and insight into the

optimality of the tactics employed.

The approach of using an expected-value war game allows, more readily, a sensitivity analysis or complete parametric study, as more situations, initial force levels, and battle termination conditions may be exercised within the latter form of the manual game, for the same effort expenditure.

B. SIMPLIFYING ASSUMPTIONS

Prior to development of the war games, and concurrent with the first attempt at the scenario, a list of simplifying assumptions was devised. The following list, by category, reflects the basic initial assumptions. More specific ones, as pertain to a specific weapon system, for example, are incorporated later in the study.

1. Situational Assumptions

a. A non-nuclear limited-general or general warfare environment.

b. Central-European-type terrain.

c. No basic changes in the political policies of the governments concerned.

d. No near-future improvements, from the defender's point of view, in the current force imbalances.

e. A general air-parity exists with Red having a slight advantage. Either side can gain local air superiority for short periods of time.

f. Red has launched his armor-heavy offensive, with little warning to Blue; the implication being that the only ground forces Blue can employ are those currently stationed in Central Europe.

g. The equivalent of a Red combined-arms army attacks each Blue forward mechanized infantry division; the assumed approximate combat power ratio being seven-to-one (7:1).

2. Organizational Assumptions

a. Red Units

(1) Basic organization is as reflected in Refs. 4 and 5 and Table I.

(2) Exceptions to (1), above, are the incorporation of Soviet-type armored equipment into the tables of organization. The T-62 (main battle tank), the BMP-76 (armored infantry combat vehicle), the BRDM (amphibious scout car and ATGM launch vehicle), and the 85mm (ATAP) replace the 100mm medium tank, APC 3, APC 4, and 57mm (ATAP), respectively.

(3) Two BRDM per motorized rifle battalion are configured as ATGM launch vehicles, mounting the "SAGGER" missile.

(4) One BMP-76 per motorized rifle platoon has a SAGGER missile mounted on a launch rail above its 76mm smooth-bore gun.

(5) Red units are at full organizational strength at the beginning of each ambush.

b. Blue Units

(1) Basic organization is as per the H-series Table of Organization and Equipment [Ref. 10].

(2) Antiarmor weapon system augmentations and replacement have given each mechanized infantry battalion 27 MAW and 18 HAW, replacing the 90mm and 106mm recoilless rifles, respectively.

(3) Each of the mechanized infantry divisions has one tank battalion equipped with the M60A2 main battle tank, which mounts the 152mm gun-launcher (-firing the A2(M) ATGM or the 152mm HE round).

3. <u>Doctrinal and Tactical Assumptions</u>

a. Red Units

(1) The Red force units attempt to move at an average speed of 15 kilometers per hour, in regimental column formations, accepting exposed flanks so as to achieve a rapid, deep penetration to the rear of the Blue main defense forces.

(2) Mobile regimental artillery is positioned close behind the attacking echelons, having a response time to targets of opportunity of from three to five minutes.

(3) Individual tank crews in Red tank platoons will normally engage the same targets engaged by their respective platoon leaders unless they detect a high threat target requiring immediate counter-action [Ref. 11].

(4) Red motorized rifle units will prefer to remain mounted in their BMP-76's, firing from firing ports in the sides of the vehicles, thus ensuring maintenance of the momentum of the attack. They will dismount only when necessary to remove or destroy obstacles, barriers, or dug-in enemy forces.

(5) Main gun fire from BMP-76's will be employed in the same manner as in (3), above.

(6) When engaging tanks or other armored fighting vehicles at ranges beyond 500 meters, the BMP-76's will halt to fire their main guns. Engaging close-range targets and

personnel, the BMP-76's will fire either main gun or coax MG, while advancing to close with the target.

b. Blue Units

(1) Due to high vulnerability of helicopters to AAA systems, employment of helicopters as AT systems are restricted to raids on highly lucrative massed armor targets such as assembly or staging areas rear of the enemy lines; or, held in general reserve to be employed as part of armor-heavy counterattacks of deep armor penetrations. The latter to be the case, especially where the enemy tanks have outdistanced, or otherwise become separted from, DS AAA weapons and armored infantry units.

(2) Due to limited combat and combat support resources and extended defensive sector frontages, mechanized infantry divisions will employ the Force-Oriented Defense, making maximum use of reinforced mech infantry platoon antiarmor ambushes.

(3) Long range ATGM fires are used to attrit the enemy force, maintain contact with the enemy's first echelon units, and draw those units into the killing zones of the small-unit antiarmor ambushes. (See Ref. 12 for a detailed discussion of such tactics by the Soviet armed forces as part of their antiarmor warfare.)

(4) Due to sparsity of friendly troops to their front and lack of massed mutually supporting fires, artillery units are positioned between one-third and two-thirds of their maximum effective ranges ahead of the first-echelon enemy units or rearward of the foremost friendly units, whichever is the

lesser distance [Ref. 8].

(5) Due to firepower superiority of the Red artillery, and presumed responsiveness to counter-battery fire missions by the Red artillery, the Blue artillery batteries normally displace after the equivalent of, at maximum, a 72-round battery volley (-one fire mission).

(6) Maximum use of artillery and mortar antiarmor ambushes is employed. (See Ref. 18 for an historical account of devastatingly effective Soviet artillery ambush of elements of four German panzer and motorized infantry divisions.)

4. Scenario Assumptions

a. Suitable ambush killing zones are available which afford a maximum capability to simultaneously detect multiple armored targets at ranges up to 3,000 meters for the ATGM systems in the ambush force.

b. Unless forced by the situation to do otherwise, the antiarmor ambush would not be executed on Red recon units of five vehicles or less.

c. The ambush force (a reinforced mech infantry platoon) achieves surprise, being undetected by Red recon units or first echelon attack forces until its initial rounds are fired. (This presupposes that detection of the ambush force elements by the Red recon unit would result in exchanges of fire such that the recon unit would be the force ambushed. It is assumed that the Blue ATGM systems would track the recon force vehicles until they had completed passage of the killing zone and no longer posed a threat to the ambushers' achievement of surprise.)

d. Blue communications is effective to the point that an ambush warning order can be relayed approximately 30 seconds before the ambush order is given, and can be received by all elements.

e. Intervisibility is such that initial hand-offs are completely effective and all ATGM systems can engage their initial assigned targets within five seconds of the end of the order to open fire; this order being given by the mech platoon leader.

f. If any Red vehicle detects the launch of an ATGM at it, it will attempt evasive action and will immediately begin the process of engaging the ATGM, unless already in the process of engaging another high-priority target.

g. The infantry portion of the ambush force will place its vehicles in covered and concealed positions (relative to the Red force) to the rear of the ambush position and near enough to allow the platoon to be mounted and moving in less than three minutes from the start of the ambush at t=0 seconds.

h. The Blue tanks will be positioned to both participate in the antiarmor ambush and provide covering fires to the withdrawing mech infantry platoon (which has no tank-killing capability while moving, the armored personnel carriers being armed with caliber .50 machine guns [Ref. 8]).

i. The Blue tanks with HAWs will continue to engage the ambushed enemy force until the mech platoon is clear, or effective counter-fire is generated from the Red force.

j. Each ATGM system must be stationary throughout the target engagement process until the missile impacts in order to achieve any reasonable probability of a hit. (Any launch vehicle movement is assumed to cause loss of missile control.)

k. Due to the general lack of opportunity to register targets in the ambush area, Blue artillery would be on call with the target area being the approximate position of the Red battalion second echelon units.

l. The Blue mechanized platoon has a quick-fire radio channel to the company's attached 4.2 inch mortar platoon and the battalion's direct support 155mm howitzer battery.

m. The Blue mech platoon will remain in firing positions approximately 30 seconds after initiation of the ambush, engaging as many Red AFV's as possible in that time. (A first estimate of the maximum allowable time before the Red AFV's can begin to bring effective fire to bear.)

n. The Blue dismounted withdrawal rate averages 10 km/h and the mounted rate is 15 km/h.

o. The Red tank battlesight ammunition is not fixed, and for initial convenience was assumed to be the appropriate type round to best kill the type target engaged in each case. (That is HVAPDS (FS) rounds were fired at all AFV's, and HEAT (FS) rounds were fired at all personnel and dismounted ATGM targets.)

p. Due to differences in required superelevations and firing ignition circuits, simultaneous engagement of targets by the main gun, coax MG, or mounted ATGM from the same AFV

are assumed to be impossible in this study.

q. Blue sniper fire is employed to the maximum extent possible in the ambushes to kill AFV commanders and drivers, or otherwise limit the commanders' abilities to detect and acquire targets and observe the battlefield. (See Ref. 12 for an excellent discussion of sniper and machine gun fire in Soviet antiarmor ambush tactics.)

C. DATA DEVELOPMENT

1. Requirements

In undertaking the development of the manual war game inherent to this study, it became apparent that the important characteristics of all the systems to be modeled had to be determined. Important characteristics were determined to be those which affected the course of the battle during the period considered. The implication here, for example, is that the fuel capacities of vehicles were not considered important due to the relatively short projected duration of each antiarmor ambush. On the other hand, all events and times involved in the target engagement processes were felt to be of importance. Similarly, system characteristics which determined short-term mobility, survivability, reliability, and target hit/kill capability were also critical.

To maintain simplicity in the model, the inherent mobility of each vehicle was assumed to provide a constant speed of 15 km/h. Survivability was assumed assured against small arms fire for all AFVs (to include external trappings) as this is an example of extreme-casing the solution - any effect resulting could then be judgmentally applied as a bonus to the firer,

but the exact effect would be indeterminable. Similarly, near misses with high explosive-type rounds were assumed to have only suppressive effects; the fragment damage to antennae, vision blocks, fording equipment, etc., being, again, bonus effects which would be contingent upon future events outside of the engagement in question.

A further simplification was the assumption that all systems were completely reliable throughout the battle, unless they were mobility-, firepower-, or catastrophic-killed.

a. Critical Event Times

In a two-sided battle such as the antiarmor ambush, the critical event times were felt to be times for target detections, target acquisitions, and target engagements. These included response/reaction times, weapon load times, system aiming times, system displacement times, target hand-off times, projectile flight times, and time delays caused by judgmentally applied indecision or suppression.

Since the distributions of all such times were not known, best estimates and, in several cases, gross approximations had to be found.

b. Hit Probabilities

As assumed under paragraph C, above, except for personnel and ground-mounted ATGMs, targets required projectile impact to be considered hit (-for other than judgmentally applied suppressive effects). The individual system hit probabilities are greatly system, target, and situationally dependent. Since few of the characteristics of Warsaw Pact-type systems or US classified ATGM systems are available, or

may be incorporated into an unclassified study, best unclassified estimates had to be found. In several cases, gross extrapolations from assumed similar systems or results of experiments were used.

c. Conditional Kill Probabilites

Normally, given a target hit by an antiarmor projectile, some damage will result. The amount of target damage or type kill was assumed to fall into one of the categories of kills: Mobility, firepower, catastrophic, or mobility-union-firepower. Since it is theoretically possible for an armored target to be hit and sustain no appreciable damage, such a hit was presumed to have had some suppressive effect. This suppression, whether it was in the form of a loss in mobility, firepower, or missile control; or, it caused a time-delay in the target's own target engagement process; was, judgmentally applied, taking into consideration the situation and systems involved. Any hit which did not result in at least a mobility-union-firepower (MUF)-kill, was assumed to fall into this suppression category.

The type of kill, given a hit, is a function of target armor characteristics, projectile penetration or spalling effect, angle of incidence to the armor (vertically), and attack angle (horizontally). (Combined within armor characteristics is the inherent standoff distance provided by external trappings or standoff plates.)

Due to the approximations necessary to determine basic hit probabilities, it was felt there would be little sense in computing conditional kill probabilities for each set of

angles, impact points, and weapon-target ranges. For simplicity of computation and comparison, average conditional kill probabilities, by category, were sought. Again, extrapolations from known or estimates values were used wherever necessary.

2. Sources and Procedures

a. Critical Event Times

Research has revealed some pertinent unclassified studies and experimental results which have produced data directly applicable to this study, with only minor modifications required. The sequence of The Tank Weapon System reports prepared by the Systems Research Group, Department of Industrial Engineering, The Ohio State University, have addressed the target engagement process times for main battle tanks [Refs. 14, 15 and 16]. Other pertinent data sources were the Combat Operations Research Group's Reference Handbook: Weapon Effectiveness Data, Part III (Weapon Data), Volumes I and II [Ref. 17]; the US Army Combat Developments Experimentation Command report: Tactical Effectiveness Testing of Antitank Missiles [Ref. 18]; the US Army Europe Pamphlet No. 30-60-1, Part One, Volumes I and II [Refs. 19 and 20]; and, the International Defense Review series on "The Modern Battle Tank" [Refs. 21 and 22].

Specific references employed are listed in Appendix A with the appropriate algorithms, tables, figures, or discussions of same.

An example of the time distribution derivations is Case I,A,1, from Tab 2 to Appendix A. This is the case of T-62 engagement of M60A2 or HAW with aimed fire, moving firer/

stationary target, first round (HVAPDS (FS)). Here one sees the general equation for time to projectile impact is a modification of that equation presented in Ref. 15. The detection times were assumed to be truncated exponentials, as shown, and the times of projectile flight were extrapolated from data on US and Soviet weapon systems presented in Refs. 17 and 22. The remaining times were assumed to be uniformly distributed, with ranges judgmentally derived. (Note that graphical derivations of the distributions of the maximums of pertinent time distributions are presented in Figs. 2 through 11.)

For purposes of incorporation within the manual war game using the "Monte Carlo" method [Ref. 23], random numbers were drawn and the appropriate values were marked on the cumulative distribution functions (CDF) of the appropriate critical time distributions. The corresponding points on the time axis were then read from the downward projections of the indicated points on the curves of the distributions. These, then, were graphical solutions to the inverse CDFs used to determine realizations of the random variables of interest. Inherently assumed, then, is the existence of inverse functions for all the CDFs utilized.

On the other hand, for the expected value approach, only the derived mean values of the distributions were used. For the case in question, above, the expected time to engage is 15.5 seconds if the T-62 detects the ATGM launch, or 23.5 seconds if the target is handed-off from another observer. (Note that all pertinent mean times are listed according to the engagement types represented as cases in Appendix A, Tab 2, Enclosure b.)

b. Hit Probabilities

The references listed under paragraph 2a, above, were used in addition to several Ballistic Research Laboratory memorandum reports and a Report on Effectiveness of HE Fire from Tank-Mounted Weapons prepared by the Battelle Memorial Institute [Ref. 24]. These and other specific references are, as in paragraph 2a, above, listed within the appropriate algorithms, tables, figures, etc., in Appendix A.

An example of the data extrapolation used for the Soviet-type weapon systems follows from the assumption that the 115mm HVAPDS (FS) round, fired with a muzzle velocity of 1,600 m/sec [Ref. 21] from the T-62 main battle tank, will have ballistic characteristics similar to the T320 APFSDS round. The T320 has a muzzle velocity of 5,200 ft/sec, a ballistic coefficient of 1.712, and is classed as a type-2 projectile [Ref. 25, Appendix A]. To derive the hit probabilities, the appropriate tables in Ref. 25 were entered using an assumed round-to-round dispersion of 0.6 mils. This, in turn, was taken from the discussion of 115mm HVAPDS accuracy in Ref. 22, and the related M60 APDS dispersion in Ref. 17.

The effect of firing while moving, with a vertically-stabilized main gun, is approximated from estimates shown in Refs. 22, 26 and 27. The characteristic shapes of the hit probability curves were then assumed being based on a few known or estimated points.

Similarly, ATGM hit probabilities, conditioned on maintenance of line-of-sight with the target, were drawn from discussions and figures presented in Refs. 28 and 29.

c. Conditional Kill Probabilities

In all cases, conditional kill probabilities were judgmentally applied extrapolations from estimates for anti-armor munitions presented in Ref. 17. The judgmental determinations were based on relative approximate ratios of vulnerable-to-presented areas, armor characteristics, weapon-target ranges (for kinetic energy rounds only), and locations of vehicular-mounted weapon systems.

The value of the P(MUF: SSH) was taken to be:
P(M: SSH) + P(F: SSH) - P(C: SSH) [Ref. 17].

III. MODEL DEVELOPMENT

The initial formulation of the scenario upon which the manual war game employing both the Monte Carlo methodology and the expected-value approach is based, is shown in Appendix A, Tab 1. The general situation and force organizations were modified versions of the classroom exercise (BG1C/M30) presented to the Infantry Officer Advanced Courses at the U. S. Army Infantry School, Fort Benning, Georgia [Ref. 4]. The Red and Blue tactics were based on the assumptions listed in Part II, B, of this study, being derived largely from References 4-7, 11, 12 and 28-32.

A. MANUAL WAR GAME

From experience gained through instruction on and use of the AIR BATTLE ANALYZER, developed by the Applied Physics Laboratory of The Johns Hopkins University for the Department of the Navy, Bureau of Naval Weapons, possible techniques for simultaneously maneuvering and creating engagements for multiple vehicles and weapon systems were suggested. A maneuvering board consisting of a composite Range-Azimuth Plot and a Range-Time Plot were made on a scale of one inch = 500 meters. The time scale ran from 0 to 270 seconds. With such a plotting system, it is possible to graphically solve time-space relationships, as vertical projections onto the Range-Time Plot automatically transform relative motion problems in the

two spatial dimensions of the Range-Azimuth Plot, into the two dimensions of space and time on the Range-Time Plot.

Given such a plotting system, it then becomes a simple matter to keep track of individual vehicle or unit movements, thus allowing rapid estimates of weapon-target ranges or intervisibilities (assuming that some form of overlay has been prepared which reflects the scenario's assumed intervisibilities). [Ref. 33 and Figure 1]

To preserve some form of realism, allowing the Red tanks to attempt some form of evasive maneuver when each detected the launch of an ATGM at it, small areas of vegetation or terrain contours were assumed to exist, within the areas of intervisibility. Due to the complexity of trying to model such line-of-sight factors, continuously, these small areas were not held fixed. It was assumed that the ATGMs were positioned and the killing zone was chosen so as to maximize the existing intervisibilities. The effect of evasive maneuvers and normal breaks in line-of-sight due to the vegetation and slight terrain contours were handled by using the results of experimental data given in Reference 18, pages 4-9.

It was assumed that the sample experimental results applied in the scenario. Therefore, for example, the probability that line-of-sight was not broken over an ATGM time of flight of t seconds was computed to be 1-P(BLOS), where P(BLOS) is read from the vertical axis of Figure 16, entering on the horizontal axis with the value t.

For bookkeeping purposes, and to retain the sequential ordering of events, several forms were created based on critical event times. This enabled the recording and examination of only significant interactions of the systems involved to be accomplished in an efficient manner. For simplicity, event times were rounded to the nearest tenth of a second. Even at this, the Monte Carlo form of the manual game took an inordinately long period of time to run. The forms employed are shown in Appendix A.

An example of the procedure is found by examining the TIME-HISTORY forms. Here, the events were entered by chronological sequencing, the times being determined by the factors leading to time-to-engage or time-to-impact of projectile. As systems were judgmentally brought into play, the sequencing procedure of events immediately followed from the required actions of all interfacing systems. (The foregoing was, of course, based on the initial assumptions as reflected in Part II, B, of this study.)

The requirement to establish an orderly process for repeated computations of engagement results led to the development of several algorithms. The algorithms were arranged according to weapon systems, targets, and types of engagement. For example, Algorithm III (Tab 2 to Appendix A) was used whenever an ATGM system engaged an AFV;Algorithm IV was for LAW and M-79 fire at AFVs); Algorithm V was used for AFV main gun fire at personnel and ground-mounted

crew-served weapons (to include MAW); and so on. (Note that specific references and assumptions pertaining to the development of each algorithm are listed with same.)

By examination of the algorithms, one sees the interaction with the scenario diagram plotted on the maneuvering board, the TIME-HISTORY form, the engagement result forms, and the applicable figures and tables. It is this interaction, plus the judgmental determination of realistic tactics based on the assumptions listed in Part II, B, of this study, which is the manual game. The algorithms indicate the points at which random numbers are drawn when employing the "Monte Carlo" methodology.

As an example of the above-stated methodology, assume that prior to time t=0 seconds, the MAW in the 3rd Squad, M_3, has been given BMP-76 number 11a as its target. This implies that Algorithm III (ATGM Engagement of AFVs:Resulting P_k) applies: Since this is the first round for M_3, and sufficient warning was given to complete target hand-off, there is no need to first employ ALGORITHMS I and II. Assume M_3 has completed its detection, identification, and localization and will fire (engage) at t=2 seconds (assuming a slight reaction time delay following the order to fire at t=0). From the scenario diagram plotted on the maneuvering board M_3 has a range to 11a of 300 meters, at t=2, and an assumed constant ATGM velocity of 200 meters per second. It is seen, then, that M_3's missile will have a time-of-flight

of 300/200=1.5 sec. Its time-to-impact, which indicates this engagement's placement on the list of critical events on the TIME-HISTORY form is 2 + 1.5 = 3.5 sec.

Step 3 of Algorithm III yields, from Figure 15, a $P(SSH:\overline{BLOS})$ = .86. $P(E:P(SSH:\overline{BLOS})$, in Step 4, is assumed to be 1.0, as this was an assigned target.

At t = 3.5 seconds, the engagement is reentered on the TIME-HISTORY form, assuming no intervening event has caused the destruction or suppression of either M_3 or 11a.

Step 5: Using the time-of-flight of 1.5 sec, Figure 16 is entered to determine that P(BLOS)=0.02. Therefore, $P(\overline{BLOS})$= 1-P(BLOS) = 0.98.

Step 6: $P(SSH)= P(SSH:\overline{BLOS})P(\overline{BLOS})=(.86)(.98)=.843$ by unconditioning.

Step 7: Assuming that the first random number drawn is less than or equal to .843, a hit is recorded. (If there were no hit, the ATGM would begin a re-engagement process wherein the times to detect and engage, given detection, would be determined from ALGORITHMs I and II, respectively. At this point, the algorithm would begin again.)

Step 9: In Table III, the pertinent conditional-kill probabilities are found. Following a random number draw (from a table of random numbers such as found in Ref. 34), a comparison is made such that the category of kill closest to being greater than or equal to the

random number is the type kill achieved. Suppose the random number is .9803. Since this is greater than all of the categories listed under BMP-76 in Table III, for the MAW type ATGM, the judgmental application of a degree of suppression would be made in the manner discussed in Part II, paragraph C. l. c, of this study. If, on the other hand, the random number were .7201, a firepower-kill would be recorded and BMP-76 number 11a would be assumed mobility-suppressed for 30 seconds, in addition to being unable to engage targets for the remainder of the battle. (Note, by being mobility-suppressed, 11a is now an easier target for other weapon systems. By convention, however, M_3 begins a new detection and engagement process, having achieved a significant kill on 11a.)

B. EXPECTED-VALUE MODEL

By contrast, an expected-value approach is a much-simplified version of the manual game. By examination of the expected value algorithms in Appendix A, Tab 2, one sees that no random numbers are drawn. The values used are always the mean, or expected, values of the time distributions concerned. The hit probabilities are read directly, and the conditional kill probabilities are computed, weighted by these hit probabilities. At this point, fractional kills on the target are recorded by category, as the category values are weighted by the hit probability.

For example, if the same situation were posed as in paragraph A above, the conditional fractional kills, by category, from Table III, would be M= .95, F= .75, C= .72, MUF= .98. From Figures 15 and 16, P(SSH) would again be = .843. Now, the fractional kills, by category, for M_3 against 11a, would be M=(.95)(.843)= .80, F=(.75)(.843)= .632, and so on.

Also note that the engagement results recording forms have been modified for the expected-value type of fractional kills.

Here, now, 11a may engage M_3 or any other target, but its combat effectiveness has been reduced such that its kill probabilities are degraded to 1- .632 = .368 times their normal values, to account for the previous engagement results. This suggests the only complicated portion of this approach, fractional kills from multiple engagements of the same target. The rule is that kills are only awarded relative to the fraction of combat effectiveness the target possessed at the beginning of the engagement. For example, achievement of a firepower kill of .5 against a target which was only at a residual firepower effectiveness of .6, due to having been F-killed at .4 on a previous engagement, would result in an awarding of a fractional kill of .3 to the second weapon system. And, the taget would now have a residual firepower effectiveness (% F) of .3.

The reader will note that the expected-value methodology, as presented, is between the straight deterministic approach and a

stochastic manual simulation. The straight deterministic, analytic approach was ruled out as an approach for this study due to the complexity of the scenario, combat dynamics, and possible objective function which would result from this mxn, heterogeneous force structure. (Note, for this conflict, breakpoints are not modeled since Blue has a specified time of withdrawal, and Red is assumed, doctrinally, to push forces until expended, and then commit new forces through.)

On the other hand, the complete manual stochastic simulation is too time consuming and does not lend itself to reiteration, that is exercising for varying force compositions, weapon-target ranges, etc.

IV. FINDINGS AND DISCUSSION OF MODEL EXERCISES

A. THE "MONTE CARLO" MANUAL WAR GAME

Although exercising the manual game was a very time consuming task, it provided a framework for analysis of variations to aspects of the proposed tactical concept and allowed the development of model logic for further, detailed modeling and analysis.

1. The results, although greatly scenario-dependent, could readily be generalized to give insight into the feasibility or optimality of the tactics employed.

a. The high initial kill rate inflicted on the RED force in the first seconds of the battle was offset in large measure as the RED force systems were brought into play, building a higher volume of fire than that possible from the defender. (See APPENDIX A, TAB 3, ENCLOSURE a.) Recall that the ambush techniques inherent to the FOD require that disengagement be possible before the RED forces can react. If this is not possible, this aspect of the tactical concept fails.

b. The initially set requirement for the mechanized infantry platoon to remain in the ambush positions until the ambush had been in progress for 30 seconds, resulted in one of the rifle squads being engaged by a RED tank while the squad was mounted and moving in its armored personnel carrier. At the point of interest, there was

no antiarmor system available to preclude the tank's engagement of and destruction of the rifle squad and its APC, at t= 156 seconds. Recall that the 30 second ambush time limit was set, based on the initial assumption that it would be 30 seconds before the RED force could begin to bring effective counterambush fires to bear (assuming that a tank could get a maximum of two main gun rounds fired in this period of time). NOTE: This same time limit was re-examined in the expected-value game in order to check the results; and, was found to yield roughly the same results, although this action was extrapolated to, beyond the point of actual game termination.

c. Main gun fire from BMP-76s, while moving, had little effect on the BLUE force; but when they halted to fire at armored targets, by the third rounds they were achieving casualty production.

d. Although artillery fires were not explicitly played, the battle results would have been virtually the same for the forces in the ambush force and the RED first echelon force caught in the killing zone. This was the case because the BLUE artillery would have been adjusted on the RED battalion's second echelon units to inhibit their effectiveness in engaging the BLUE force by fire or maneuvering on that force in its ambush positions or during its withdrawal. The RED artillery was assumed to have a three to five minute delay time, and, as such, was the basis for the decision that all BLUE elements be mounted and moving prior to t= 180 seconds.

2. Structure-wise the manual game is complicated in that it requires the simultaneous manipulation of several forms, figures, tables, and a plotting board. But this form has the advantage of being modular in nature, allowing the easy substitution of classified system characteristics or known critical event time distributions where herein they may have been assumed, based on intuition alone.

3. Some of the simplifying assumptions do provide what may eventually prove to be great breaks with reality; for example, the whole effectiveness of the ambush technique presupposes an ability to avoid detection by the attacking force until the initial rounds are fired. Another implicit assumption is that the RED AFVs could conduct evasive maneuvers from the BLUE ATGMs, while initiating counter-engagement procedures. This may seem to be contradictory in nature, but it was assumed that such could somehow be effected.

B. THE EXPECTED-VALUE MANUAL WAR GAME

Due to the form of some of the critical event time distributions, use of the mean value to represent the expected value slightly biases the times toward the longer values. This is the case with non-symmetrical distributions such as the exponential, wherein more than 50% of the observed values will be less than the mean. For this reason, the distributions for other than the uniform random variables were plotted, and, in some cases, graphically derived, so that the user could use median values, if such were the choice. (See

APPENDIX A, TAB 2, ENCLOSURE b.) Note that some of the critical event distributions were modified during research and development of the expected-value game; therefore, pairwise comparison of game results, except where the comparison is obvious, is not recommended.

1. The BLUE force achieved a significantly favorable force exchange ratio of 8.75:1 during the initial 16.3 seconds of the battle, but this advantage rapidly deteriorated to 2.7:1 at the original mechanized infantry platoon withdrawal time of t= 30 seconds, and was down to 1.6:1 when the game was terminated at t= 40.5. The next time of possible RED system attrition would have been at t= 54.3, while many RED system firings were scheduled in the first few seconds after game termination.

2. The values of the exchange ratios listed in paragraph 1, above, are dependent upon the weights assigned to the various systems examined. Although the weightings were judgmentally determined, they are similar to the most widely used modeling tool for measuring combat power: firepower potential scores. The actual weights used were judgmental modifications, by the author, of firepower potential scores, as listed in Reference 9, and an unclassified version of the standard weapon system weightings employed in the Weapon Effectiveness Indices/Weighted Unit Values methodology. (See TABLE VI.) [Refs. 35 and 36]

3. With the exception of the significant kills achieved on the MAWs, the greatest single BLUE attrition factor was the fire of the two BMP-76s in the first echelon armed with SAGGER ATGMs. (Note the large increases in the cumulative losses at t= 32.4 and 37.8 on Figure 28.)

4. Removal of the two high MAW losses and the RED ATGM kills reduces the locus of points for the BLUE force in Figure 28 to a relatively constant slope (loss rate) which reaches a maximum at t= 40.5 of 45.493 points. This implies a resultant exchange ratio of approximately four-to-one. Such removal would be accomplished by early engagement of the RED ATGM launch vehicles and an earlier withdrawal of the BLUE infantry elements.

5. An attractive feature of positioning the HAW and M60A2 at greater ranges than exercised in this model is shown by the following: Extending the range of initial engagement from 2000 to 2500 meters causes the P(C-Kill)s on T-62s of (.92)(.7)(.6)= .386 for the HAW, and (.92)(.65)(.55)= .329 for the M60A2, to be decreased to .363 and .320, respectively; whereas, the T-62's P(C-Kill) on an APC-size target will decrease from .028 (on the first round, while moving) to virtually zero since it is questionable if the kinetic energy round would penetrate the required depth of armor at extreme ranges [Ref. 21], given that it did hit. This range extension then offsets the increased relative superiority in rate of fire which the RED AFV possesses. (Note, the RED gun systems may continue to fire at

approximately the same rate, while the BLUE ATGMs have an additional 1.5 to 2.5 seconds of projectile flight and, therefore time between rounds.)

approximately the same rate, while the BLUE ATOMs have an additional 1.5 to 2.5 seconds of projectile flight and, therefore time between rounds :

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Given the validity of the scenario assumptions relative to tactics, and the appropriateness of the critical event time distributions, the tactic of having the mechanized infantry platoon continue engaging targets until t= 30 seconds is not feasible as it results in losses to the infantry force and requires that the M60A2s and HAWs initially engage the RED tanks which are the highest threats to the infantry in this situation, and continue to do so until the infantry force has disengaged. This, in turn, results in higher loss rates for these systems as the RED ATGM launch vehicles are left unengaged and capable, in turn, of engaging and killing the BLUE ATGM systems.

2. In line with an earlier infantry disengagement, at around t= 5 to 10 seconds, the BLUE ATGMs should have as their first priority, the destruction of the overwatching RED ATGM launch vehicles.

3. In order to preclude RED armor maneuvering on the withdrawing infantry before they can completely disengage, the M60A2s must be in positions which afford observation and fire in the vicinity of the infantry routes of withdrawal. This might necessitate displacement after the first few rounds into the killing zone, in order to reach such overwatch positions.

4. The RED ATGM launch vehicles in the first echelon force are the greatest threat to the M60A2s and the HAWs, therefore, these must be engaged and destroyed early in the battle. This then allows more flexibility in the engagement of the other RED AFVs.

5. The placement of weapon systems in the ambush positions was critical to the determination of when to withdraw the mechanized infantry platoon, and when to displace the reinforcing ATGMs. Trade-offs exist between longer engagement times and longer ranges of engagement.

6. There was a trade-off relative to the suppressive effects versus kill probabilities for the main gun versus machine gun fire from the RED BMP-76s at personnel and ground-mounted, crew-served weapons. The advisability of firing the unstabilized 76mm smooth-bore gun from the halt at long range armor targets was suggested due to the low single shot hit probability achieved when firing on the move. On the other hand, the possible increased suppressive effect of the coaxially-mounted machine gun in engaging closer personnel targets was suggested, given that it was assumed the BMP-76s will attempt to close with the enemy infantry as quickly as possible.

7. Modeling the ambush engagement in isolation of supporting artillery fires was assumed to be permissible due to the lack of utilization of such fires directly within the killing zone, within the first three-to-five minutes of the battle. For this reason, the results

of each ambush may be analyzed in isolation, but may not be carried forward to the next engagement until the expected effects of supporting fires from both sides are incorporated. This analysis applies only to the gaining of additional modeling insight, since accurate determination of exchange ratios and loss rates must include the effects of supporting fires.

B. RECOMMENDATIONS

It is recommended that the manual war games be utilized and modified, as necessary, by military personnel in the combat arms to further explore tactical restraints required under varied scenario conditions such as increasing the density of RED ATGM systems in the first echelon, altering the initial engagement ranges, or changing the orders of battle.

It is further recommended that the modeling assumptions be examined by personnel involved in high resolution simulations of the Force-Oriented Defense to assist in establishing the bases for initial runs.

APPENDIX A:

THE MANUAL WAR GAME

This appendix presents the component parts of the manual game as it was developed. Figure 1 reflects the base-case scenario disposition of forces at the time of initiation of the ambush. Note that the weapon-target ranges are measured from center mass of each symbol used.

To further present, as concisely as possible, the base-case scenario as it was exercised, the appendix includes pertinent extracts of the exercise reflected on the type record forms used.

TAB 1 (The Manual Game: Procedures and Rules) to this appendix sets the stage and initiates the sequencing of the game.

TAB 2 (Elements of the Manual Game) to this appendix provides the pertinent critical event time distributions, figures and tables of hit probabilities and conditional kill probabilities, and the algorithms with which critical event times and engagement results are determined.

TAB 3 (Analysis of Exercise Results) to this appendix includes the aforementioned sample record forms, on which are reflected some of the engagement results, in order to clarify the analysis and the methodology employed.

(The Manual War Game: Procedures and Rules) to APPENDIX A. TAB 1.

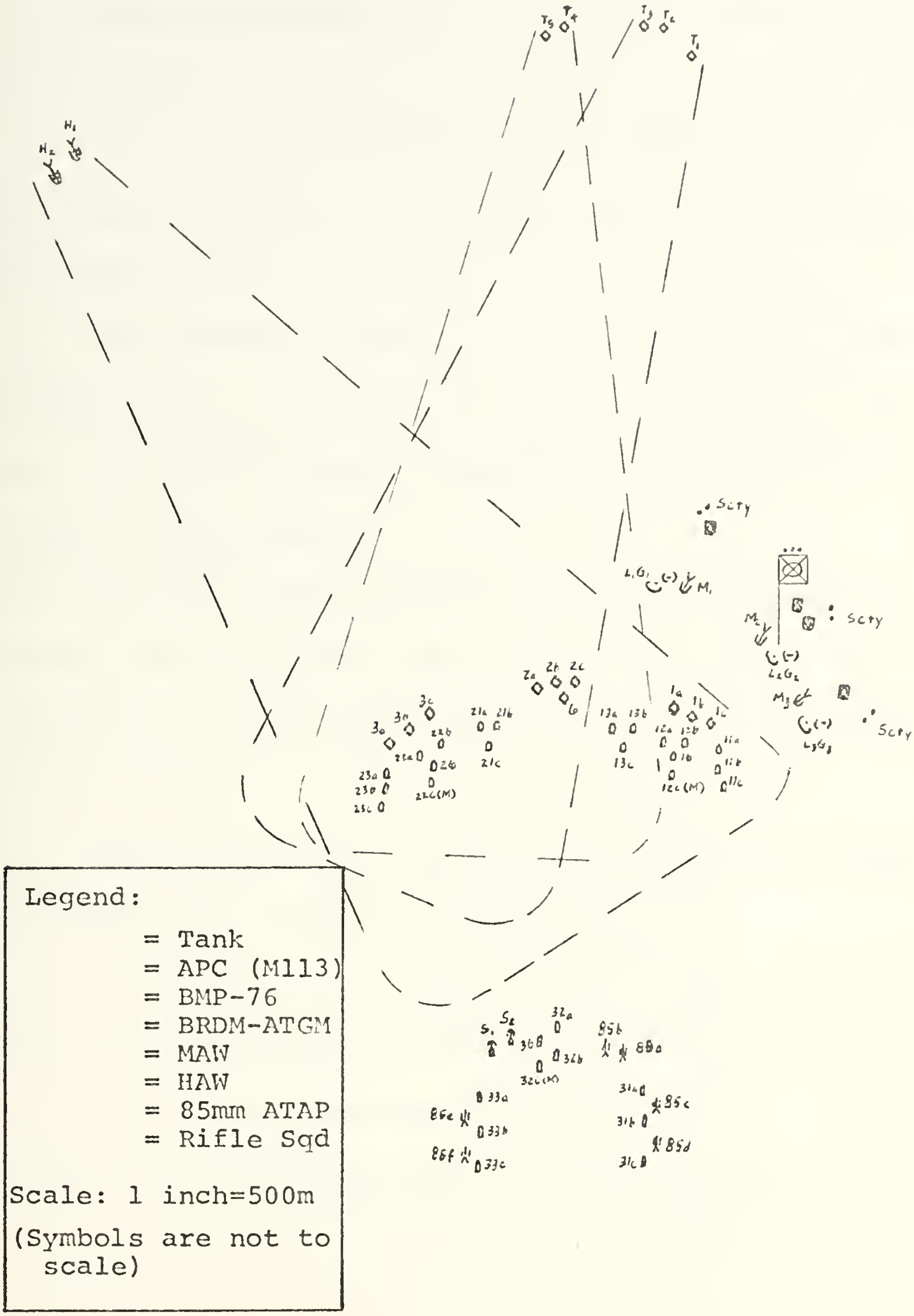

Figure 1. Scenario Diagram: Initial Dispositions.

A. PROCEDURES

1. Select an appropriate order of battle for both RED and BLUE.

2. Given an ambush killing zone at least 1000 meters in diameter, position the ambush force and determine appropriate zones of intervisibility.

3. Select appropriate formations for the RED first and second echelon forces.

4. Place the RED force, in these formations, with the first echelon unit in the killing zone.

5. Assuming an ambush initiation order given, judgmentally assign firing times to all BLUE weapon systems (abort those, such as LAW or M-79, which may have P(SSH)s which are too low) within the first five seconds.

6. Enter the appropriate algorithms to begin the target engagement processes. (See TAB 2, this appendix.)

7. Record on FORM A (TIME-HISTORY) the calculated impact times for each engagement. As these times become the next critical events, re-enter the engagement on FORM A, compute and record the engagement results. (Round all times to the nearest tenth of a second.)

8. Judgmentally bring each system, on both sides, into play in as realistic a manner as possible. As each begins its target detection and target engagement process, the sequence of critical event times is automatically generated.

9. Use the TIME-HISTORY form to keep track of the next critical events.

10. Remove BLUE systems to covered and concealed positions as they become mobility or firepower-killed. (For the expected-value game, this is begun when the cumulative fractional catastrophic kill reaches or exceeds .50, or the MUF-kill on any one hit is greater than or equal to .75.)

11. Begin withdrawal of BLUE mech infantry platoon weapon systems and personnel at or before t= 30 seconds. The only exception is for a MAW gunner who has launched his missile prior to t=30; in which case, withdrawal for that gunner would begin immediately following missile impact.

12. Withdrawing personnel will be moved by the most direct route at 10 km/h to the APCs. Load time for the APCs is assumed to be 15 seconds.

13. Keep track of all current positions through plotting movements on the scenario diagram (maneuvering board).

14. Judgmentally terminate the engagements when the BLUE mech infantry platoon is mounted and moving, or prior to t= 180 seconds, whichever is sooner.

15. Assume RED systems will continue area fire once the BLUE systems withdraw.

B. BASIC DECISION RULES

1. Automatically delay, by five to ten seconds, times to begin target detection/acquisition for RED AFVs belonging to company commanders, due to the assumption that they will initially attempt to make estimates of the situation, issue pertinent orders to subordinates, report to higher headquarters, and request supporting fires.

2. For the expected-value game, a BLUE ATGM will not re-engage the same target if P(MUF-KILL)=.75 for that round, or if the cumulative fractional catastrophic kill on that target has become greater than or equal to .50. Otherwise re-engage unless a higher priority (threat) target is available. (The degree and realism of the threat is judgmentally determined.)

3. For the "Monte Carlo" form of the manual game, assume a system will only re-engage targets which have been hit when those targets still pose a threat to the firer (or, for BLUE systems, a threat to the mech infantry platoon).

4. Priority of targets for BLUE M60A2s are tanks maneuvering on the mech infantry platoon or which pose a high threat to the BLUE tanks.

TAB 2 (Elements of the Manual Game) to APPENDIX A

Within this tab are listed the critical event time distributions (ENCLOSURE a and ENCLOSURE b), figures and tables relative to hit probabilities and conditional kill probabilities (ENCLOSURE c), and the sets of algorithms for both the "Monte Carlo"-type game (ENCLOSURE d) and the expected-value game (ENCLOSURE e).

Co-located with the materials are the specific assumptions and indications of the references used in their derivations.

ENCLOSURE a. (Definition of Symbols) to APPENDIX A, TAB 2

T_a	=	Time to alert crew and prepare for the firing instructions.
$T_{a/m}$	=	Time to adjust subsequent rounds
T_{be}	=	Time for ATGM to begin engagement procedures = $\max(T_{d_j}, T_\lambda)$, $j=1, 2$.
T_{d_1}	=	Time to detect target for first time, given line-of-sight.
T_{d_2}	=	Time to detect target, given target handed-off.
T_e	=	Time to engage target, given target detected = T_1, T_m, T_h as appropriate.
T_f	=	Time of flight of projectile.
T_h	=	Time to fire subsequent round, given first hits.
T_i	=	Time to projectile impact = T_e+T_f.
T_L	=	Time to make final lay (first round).
T_λ	=	Time to select ammunition and load gun.
T_m	=	Time to fire subsequent round, given previous round misses.
T_1	=	Time to fire first round, given a detection.
T_R	=	Time to range on target.
T_s	=	Time to swing gun roughly on target.
T_σ	=	Time to sense round.
T_{st}	=	Time to stop vehicle moving 15 km/h.

NOTE: T_j is a realization of the random variable T_j, for all j.

$\bar{T}_j$ is the mean or expected value of T_j, for all j.

ENCLOSURE b (Basic Assumptions and References by Engagement Types) to APPENDIX A, TAB 2

1. Engagement types have the form: i, j, k, l, m, where

i	=	1, 2.	First or subsequent round at the same target.
j	=	D, A.	D is direct/aimed fire. A is area/indirect fire.
k	=	M, S.	M is moving firer. S is stationary firer.
l	=	M, S.	M is moving target. S is stationary target.
m	=	M, H.	M is previous round misses, H is previous round hits.
			1 Detection without external assistance.
			2 Detection involving direction from external source (Hand-off).

2. Detection and Engagement Times by Engagement Types:

(Unless otherwise referenced, distributions are judgmentally derived and simplified.)

References/Assumptions

a. 1DMS1 (-2, 1DMM1, -2, 1DSS1, -2, or 2DMMM)

(1) Tank: $T_i = (T_{d_1}$ or $T_{d_2}) +$

$T_1 + T_f$ — Assume stabilized gun. [Refs. 21 and 22]

$P(T_{d_1}$ t) $1-\exp(-0.5t), t \leq 9.2$; $1, t > 9.2$; 0, otherwise — Assume exponential (0.5) truncated at t=9.2 sec. See CDF Figure 2.

$\bar{t}_{d_1} = 2$ sec

$P(T_{d_2} \leq t) =$ $1-\exp(-0.1t), t \leq 46$; $1, t > 46$; 0, otherwise — Assume exponential (0.1) truncated at t=46 sec. see CDF Figure 3.

$\bar{t}_{d_2} = 10$ sec

$T_1 = T_a + T_s + T_R + T_L$ — Ref. 15, page 129.

$P(T_a \leq t) =$ $(t-3)/6, 3 \leq t \leq 9$; $1, t > 9$; 0, otherwise — Assume U [3, 9]

$\bar{t}_a = 6$

$P(T_s \leq t) =$	$t-1$, $1 \leq t \leq 2$ 1, $t > 2$ 0, otherwise $t_s = (\pi/4)/.525$ $= 1.5$ sec	$t_s = \theta/a$, where θ is the angle of turret traverse and a is the rate of turret traverse [Ref. 22] Assume U [1, 2]
$P(T_R \leq t) =$	$(t-.5)/5$, $.5 \leq t \leq 5.5$ 1, $t > 5.5$ 0, otherwise $\bar{t}_R = 3$ sec	Assume U [.5, 5.5] and independent of range due to use of target-height comparison graticules [Ref. 21].
$P(T_L \leq t) =$	$(t-2)/2$, $2 \leq t \leq 4$ 1, $t > 4$ 0, otherwise $\bar{t}_L = 3$ sec	Assume U [2, 4]

t_f is determined from Figure

$\bar{t}_i = t_f + 15.5$ sec	Without hand-off
$\bar{t}_i = t_f + 23.5$ sec	With hand-off

For 1DSS1 (or-2) where tank is initially moving: $T_1 = T_a + \max(T_{st}, T_s) + T_R + T_L$ — Assume $T_{st} \sim U[1.5, 3.5]$

$P(\max(T_{st}, T_s) = t =$ — Assume T_{st} and T_s are independent. See CDF Figure 10.

$(t^2 - 2.5t + 1.5)/2$, $1.5 \leq t \leq 2$
$(t-1.5)/2$, $2 < t \leq 3.5$
1, $t > 3.5$
0, otherwise
$\bar{t}_{\max(t_{st}, t_s)} = 2.5$ sec

Add 1 sec to each $\bar{t}_i$, above.

(2) 1DSS1 (or-2) for BMP-76, AG or AT guns — Assume unstabilized guns.

$T_i = (T_{d_1} \text{ or } T_{d_2}) + T_1 + T_f$ — Assume T_{d_1}, T_{d_2} and T_a are same as for tank

$T_1 = T_a + T_s + R_R + T_L$

$P(T_s \leq t) =$	$(t-1)/6$, $1 \leq t \leq 7$ 1, $t > 7$ 0, otherwise $\bar{t}_s = 4$ sec	Assume U [1, 7]

$P(T_R \le t) =$ $(t-2)/6,\ 2 \le t \le 8$ Assume U[2, 8]
$1\quad ,\ t > 8$
$0\quad ,$ otherwise
$\bar{t}_R = 5$ sec

$P(T_L \le t) =$ $(t-2)/3,\ 2 \le t \le 5$ Assume U [2, 5]
$1\quad ,\ t > 5$
$0\quad ,$ otherwise
$\bar{t}_L = 3.5$ sec

t_f is determined from Figure

$\bar{t}_i = t_f + 20.5$ sec Without hand-off.

$\bar{t}_i = t_f + 28.5$ sec With hand-off.

For 1DSS1 where BMP or AG is initially moving: $T_1 = T_a + \max(T_{st}, T_s) + T_R + T_L$ Assume $T_{st} \sim U\,[1.5, 3.5]$

$P(\max(T_{st}, T_s) = t) =$ Assume T_{st} and T_s are independent.
$(t^2 - 2.5t + 1.5)/12,\ 1.5 \le t \le 3.5$
$(t-1)/6,\quad 3.5 < t \le 7$ See CDF Figure 11.
$1\quad ,\quad t > 7$
$0\quad ,$ otherwise Add 0.2 sec to each
$\bar{t}_{\max(t_{st}, t_s)} = 4.165 = 4.2$ sec
$\bar{t}_i$, above.

(3) 1DSS1 (1DSM1, 2DSSM, or 2DSMM) for all ATGM AT wpns

(a) For BLUE ATGM AT wpns[1] Assume engagement process follows loading.

$T_{be} = \max(T_d, T_\lambda)$

$P(T_d \le t) =$ $1 - \exp(-.2t),\ 0 \le t \le 24$ Assume exponential (.2) truncated at $t_d = 24$ sec
$1\quad ,\ t > 24$
$0\quad ,$ otherwise
$\bar{t}_d = 5$ sec

$P(T_\lambda \le t) =$ $(t-4)/4,\quad 4 \le t \le 8$ Assume U [4, 8]
$1\quad ,\ t > 8$
$0\quad ,$ otherwise
$\bar{t}_\lambda = 6$ sec

---

[1] For first round of ambush, $t_d = 0$ and t_e is U [0.5] by assumption. Value of t_e is judgmentally determined.

$P(T_{be} \leq t) =$	$(1-\exp(-.2t)(t-4)/4, \; 4 \leq t \leq 8$	Assume T_d, T are independent.
	$1-\exp(-.2t) \quad , \; 8 < t$	
	$0 \quad , \text{ otherwise}$	See CDF Figure 4.
	$\bar{t}_{be} = 7.312 = 7.3$ sec	
	For BLUE ATGM, given target detected:	Following distributions derived from given median values and sample curves found in Ref. 18.
	$T_e = T_1, T_m, T_h$	
MAW: $P(T_e \leq t) =$	$1-\exp(-.082t), \; t \geq 0$	See CDF Figure 5.
	$0 \quad , \text{ otherwise}$	
	$\bar{t}_e = 12.2$ sec	
HAW: $P(T_e \leq t) =$	$1-\exp(-.087t), \; t > 0$	See CDF Figure 6.
	$0 \quad , \text{ otherwise}$	
	$\bar{t}_e = 11.5$ sec	
A2(M): $P(T_e \leq t) =$	$1-\exp(-.063t), \; t > 0$	See CDF Figure 7.
	$0 \quad , \text{ otherwise}$	
	$\bar{t}_e = 15.9$ sec	

$\bar{t}_i = t_f + \bar{t}_d + \bar{t}_e$, $t_f =$ range/missile speed

MAW: $t_f = R/200$ m/sec

HAW: $t_f = R/300$ m/sec

A2(M): $t_f = R/224$ m/sec
[Ref. 29, p. 49]

For LAW and M-79: 1DSS1, (1DSM1, 1ASS1, 1ASM1)

$T_{be} = \max(T_d, T_\lambda)$ — Assume same as for BLUE ATGM.

$T_1 = T_e$ — Assume N(5, 1)

$$P(T_e \leq t) = \begin{cases} \int_1^t 1/(2\pi)^{.5} \exp(-(x-5)^2/2)dx, & 1 \leq t \leq 9 \\ 1 & , t > 9 \\ 0 & , \text{otherwise} \end{cases}$$

See CDF Figure 9.

$\bar{t}_e = 5$ sec

(b) For RED ATGM: 1DSS1 or -2 Assume initially moving.

$T_{be}=\max(T_{st}, T_{d_1})$

or $\max(T_{st}, T_{d_2})$

Assume BMP-76(M) has only one missile and BRDM(M) may launch subsequent missiles as soon as new target detected (following previous missile impact) for up to three missiles. Therefore $T_{be}=T_{d_1}, T_{d_2}$, where T_{d_1} and T_{d_2} are the same as for tanks. See CDF Figures 2 and 3.

$P(T_{be}=t)=$ $1-\exp(-.5t))(t-1.5)/2$, $1.5\le t\le 3.5$
$1-\exp(-.5t)$, $3.5<t\le 9.2$
1, $t>9.2$
0, otherwise

$t_{be_d} = 2.984 \doteq 3$ sec

$P(T_{be}=t) =$ $(1-\exp(-.1t))(t-1.5)/2$, $1.5\le t\le 3.5$
$1-\exp(-.1t)$, $3.5<t\le 46$
1, $t>46$
0, otherwise

$\bar{t}_{be_{d_2}} = 7.823 \doteq 7.8$ sec

$P(T_1=t)=1-\exp(-.087t)$, t 0
0, otherwise
$t_1 = 11.5$ sec

Assume same as HAW. See CDF Figure 6. SAGGER: $t_f = R/200$ m/sec

$\bar{t}_i=t_f+\bar{t}_{be}+\bar{t}_1$

(c) For RED AT guns: 1DSS1 (-2, 1DSM1, -2, 1ASS1, -2, 1ASM1, or -2)

$T_{be}=\max(T_{st}, T_{d_1})$, j=1, 2 — See CDF Figures 2 and 3.

$T_1=T_a+T_s+T_R+T_L$ — Assume T_a same as for tank.

$P(T_s=t)=\int_{10}^{t} 1/(2\pi)^{.5}\exp(-(x-20)^2/12.5)dx$, for $10\le t\le 30$
1, $t>30$
0, otherwise

$\bar{t}_s = 20$ sec

Assume N(20, 6.25). See CDF Figure 12.

$P(T_R+T_L \le t) = \int_{5.5}^{t} 1/(2\pi)^{.5} \exp(-(x-11.5)^2/4.5)dx$ — Assume $N(11.5, 2.85)$ [Ref. 17]

for $5.5 \le t \le 17.5$

$1 \quad , \; t > 17.5$ — See CDF Figure 13.

$0 \quad , \;$ otherwise.

$\bar{t}_R + T_L = 11.5$ sec

t_f is determined from Figure [Ref. 17 and 20]

b. 2DMSM (or 2DSSM)

BMP-76 or AG

(1) Tank: $T_m = \max((T_\sigma + T_{a/m}), T_\lambda)$ — Approx. equal $T_\sigma + T_{a/m}$

$P(T_m \le t) = \int_{4}^{t} 1/(2\pi)^{.5} \exp(-(x-8)^2/2)dx,$ — Assume $N(8, 1)$

for $4 \le t \le 12$ — See CDF Figure 8.

$1 \quad , \; t > 12$ — Ref. 15, page 129.

$0 \quad , \;$ otherwise

$\bar{t}_m = 8$ sec — $\bar{t}_i = t_f + \bar{t}_m$

(2) RED ATGM: 2DSSM (or 2DSMM)[1]

$T_m = T_s + T_L$ — Assume T is time to switch to next missile, U [1, 3]

$P(T_s = t) = (t-1)/2, \; 1 = t = 3$

$1 \quad , \; t \; 3$

$0 \quad , \;$ otherwise

$\bar{t}_s = 2$ sec

$P(T_L \le t) = \int_{4}^{t} 1/(2\pi)^{.5} \exp(-(x-8)^2/2)dx,$ — Assume $N(8, 1)$

for $4 \le t \le 12$ — Use CDF Figure 8.

$1 \quad , \; t > 12$

$0 \quad , \;$ otherwise

$\bar{t}_L = 8$ sec

(3) RED AT guns: 2DSSM (2DSMM, 2DSSH, 2DSMH, 2ASSM, 2ASMM, 2ASSH, or 2ASMH)

$T_m = T_h = T_R + T_L$ — Same as above.

(4) For LAW and M-79: 2DSSM,(-H, 2DSMM, -H, 2ASSM, -H, 2ASMM, -H)

$T_{be} = T_{\lambda}$	Same as T for BLUE ATGM.
$T_{l} = T_{m} = T_{h} = T_{e}$	See CDF Figure 8. [Refs. 8 and 37]
LAW: t_f = range/145 m/sec M-79: t_f = range/76 m/sec	Assume constant due to relatively short range of both LAW and M-79.

c. 2DMSH (2DMMH, 2DSSH)

Tank; BMP-76, or Assault Gun:

$T_h = \max(T_{\sigma}, T_{\lambda})$

$$P(T_h = t) = \begin{cases} (t-4.5)/3.5, & 4.5 \leq t \leq 8 \\ 1, & t > 8 \\ 0, & \text{otherwise} \end{cases}$$

$\bar{t}_h = 6.25 \doteq 6.3$ sec

Assume approximately U [4.5, 8]. See CDF Figure 9.

d. 2AMSM (2AMSH, 2AMMM, or 2AMMH)

BMP-76 or Assault Gun:

$T_m = T_h = T_e = \max(T_{\sigma}, T_{\lambda}) + T_s + T_R + T_L$

Assume max $(T_{\sigma}, T_{\lambda})$ is same as for tank, above.

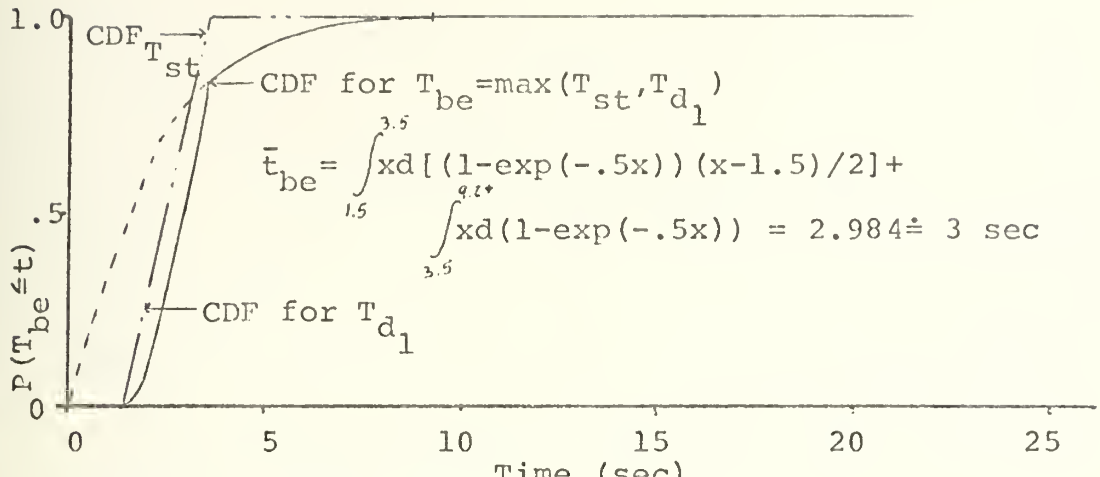

Figure 2. CDF_1 of T_{be}

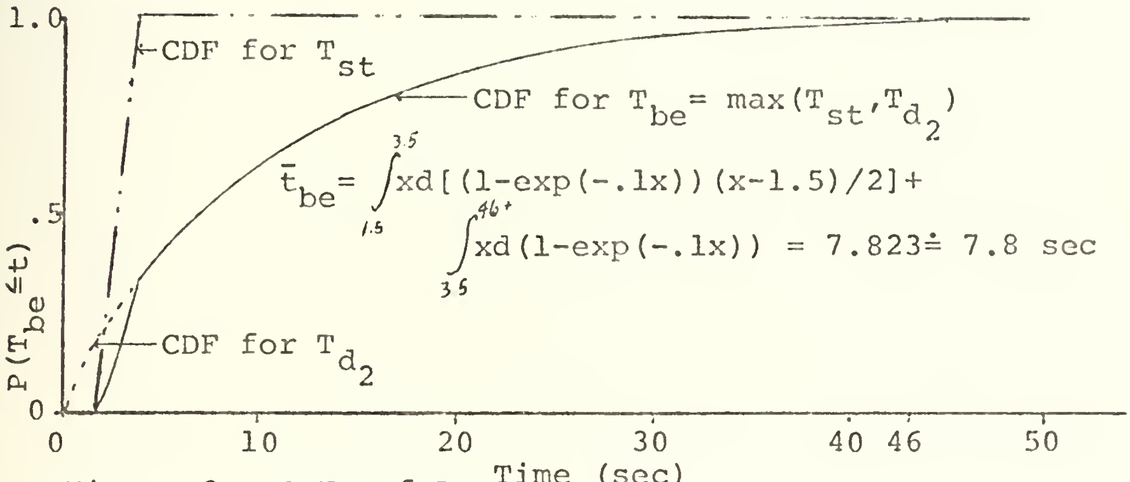

Figure 3. CDF_2 of T_{be}

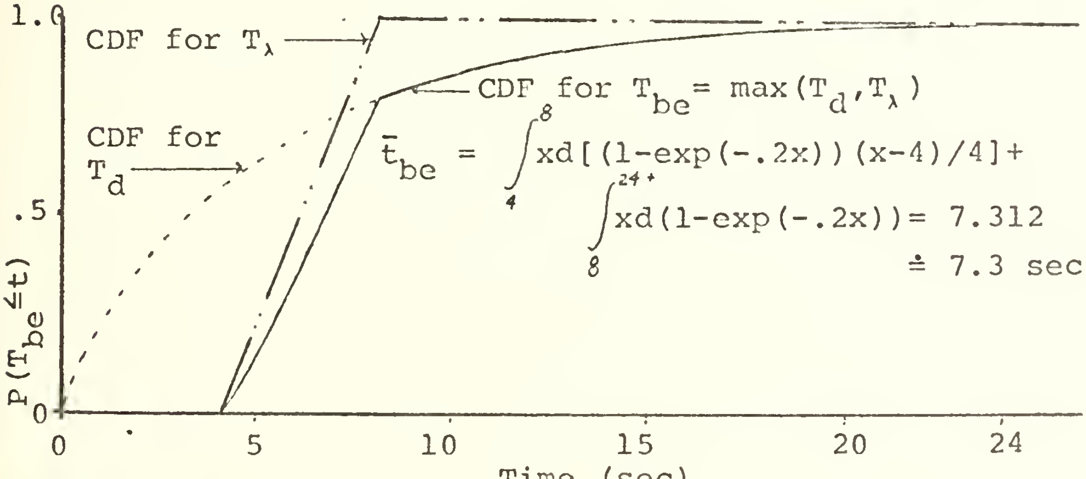

Figure 4. CDF_3 of T_{be}

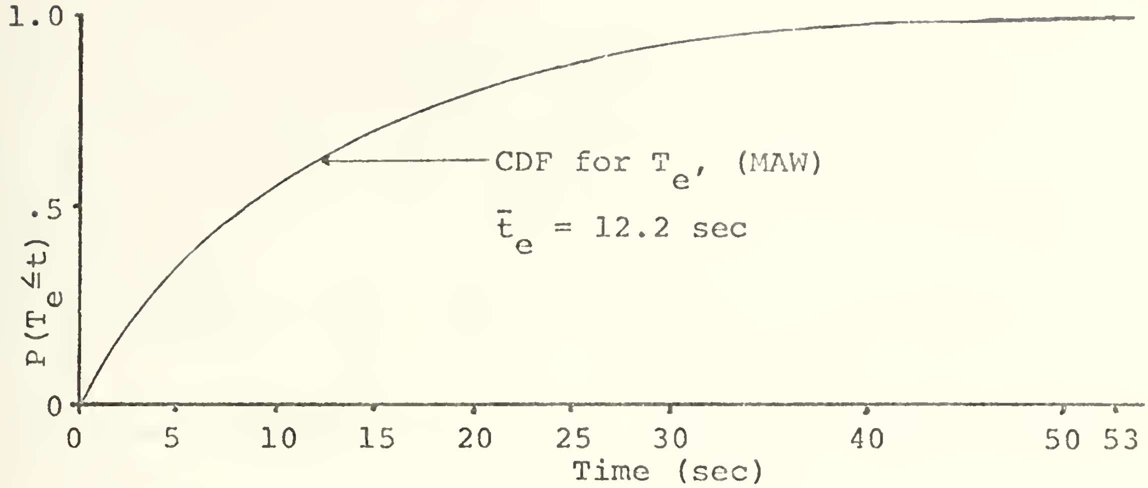

Figure 5. CDF_1 of T_e

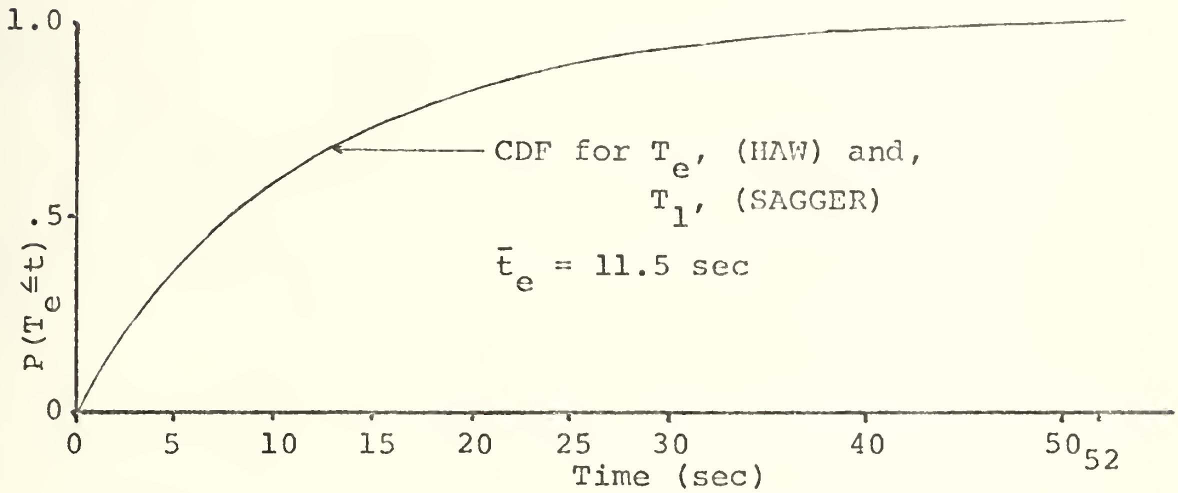

Figure 6. CDF_2 of T_e

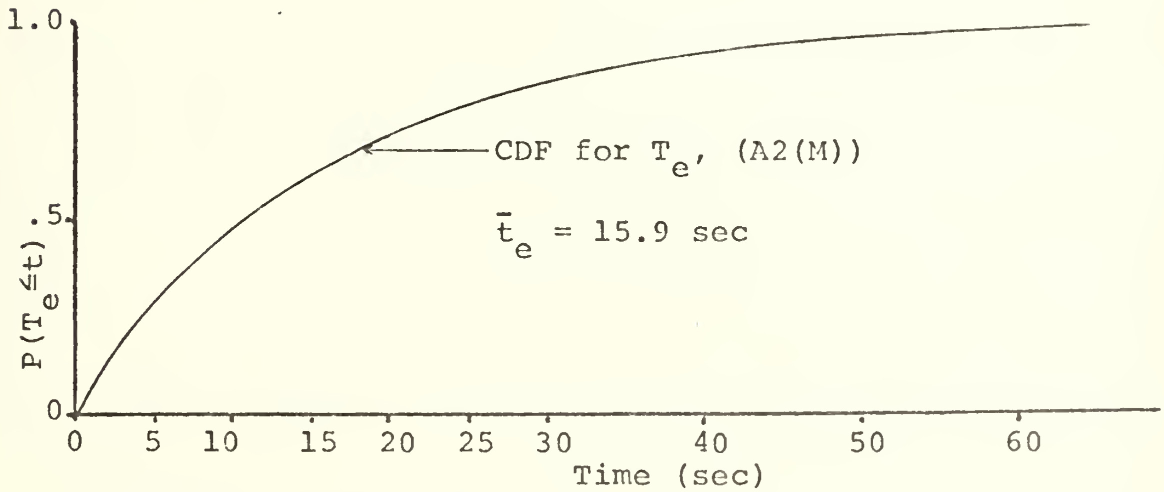

Figure 7. CDF_3 of T_e

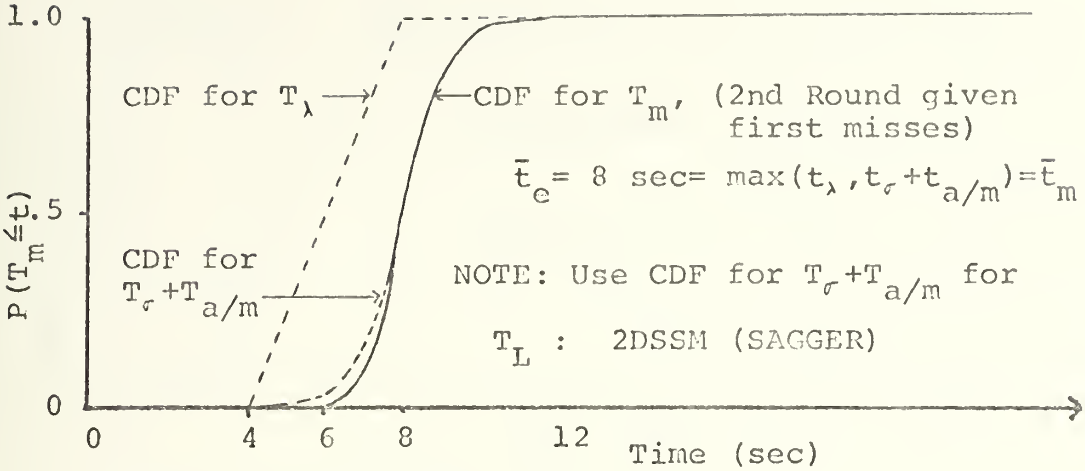

Figure 8. CDF of T_m

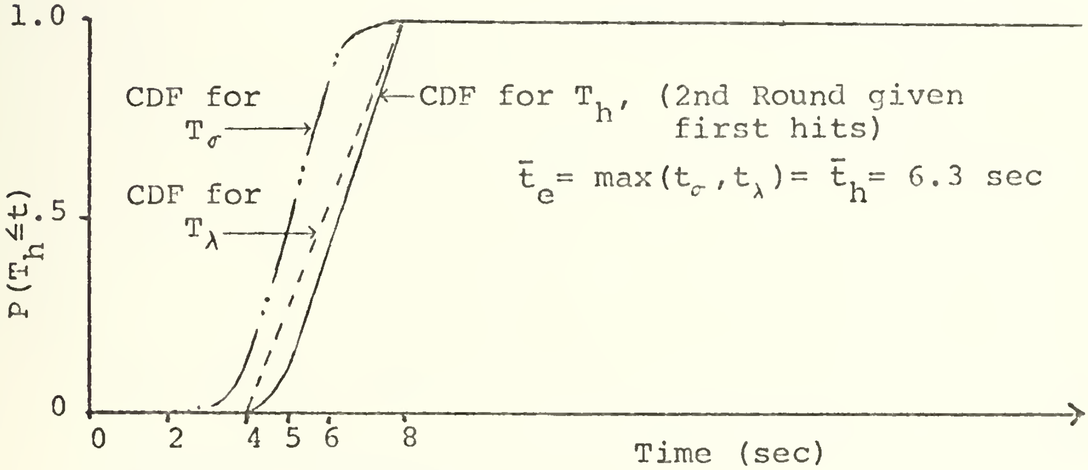

Figure 9. CDF of T_h

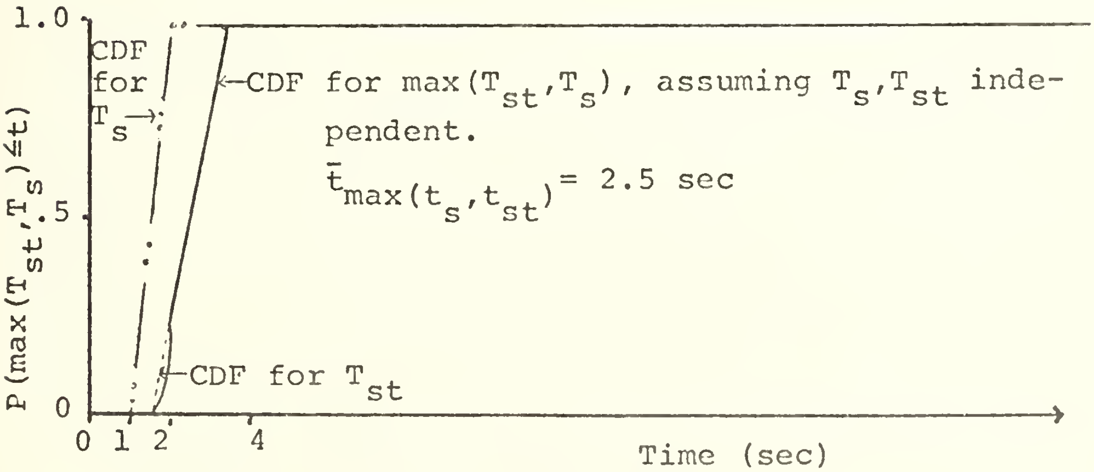

Figure 10. CDF_1 of $\max(T_{st}, T_s)$

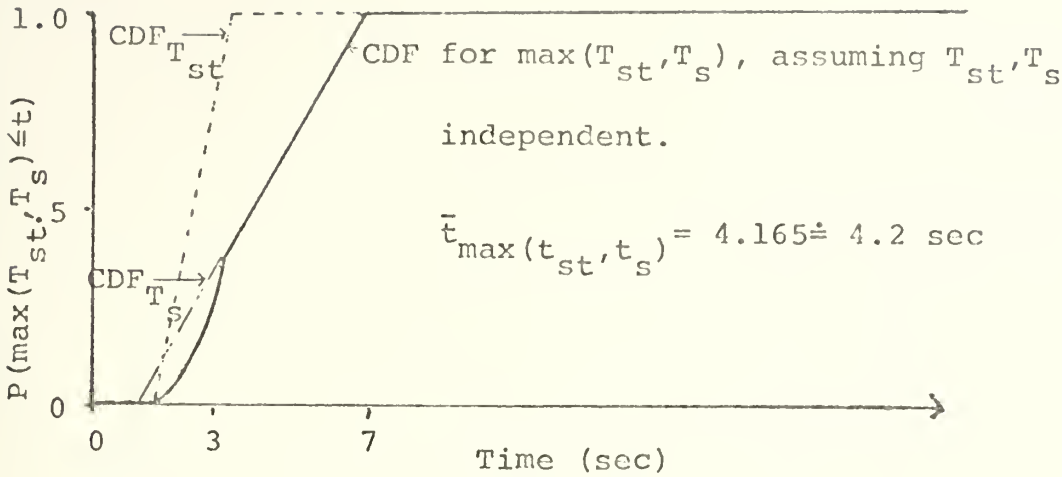

Figure 11. CDF_2 of $\max(T_{st},T_s)$

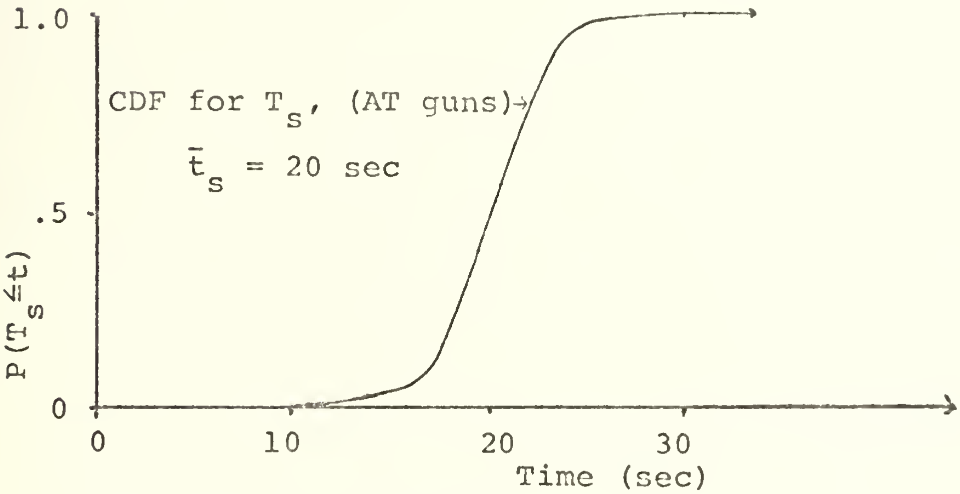

Figure 12. CDF of T_s

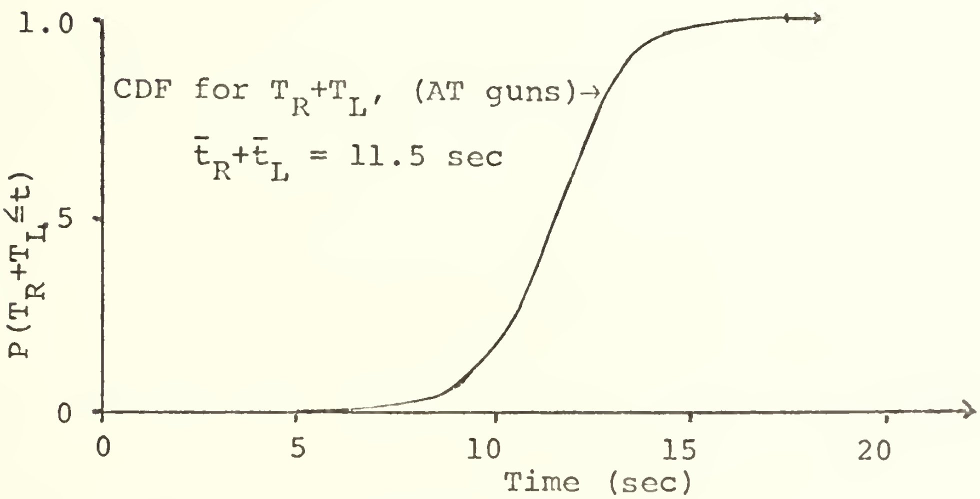

Figure 13. CDF of (T_R+T_L)

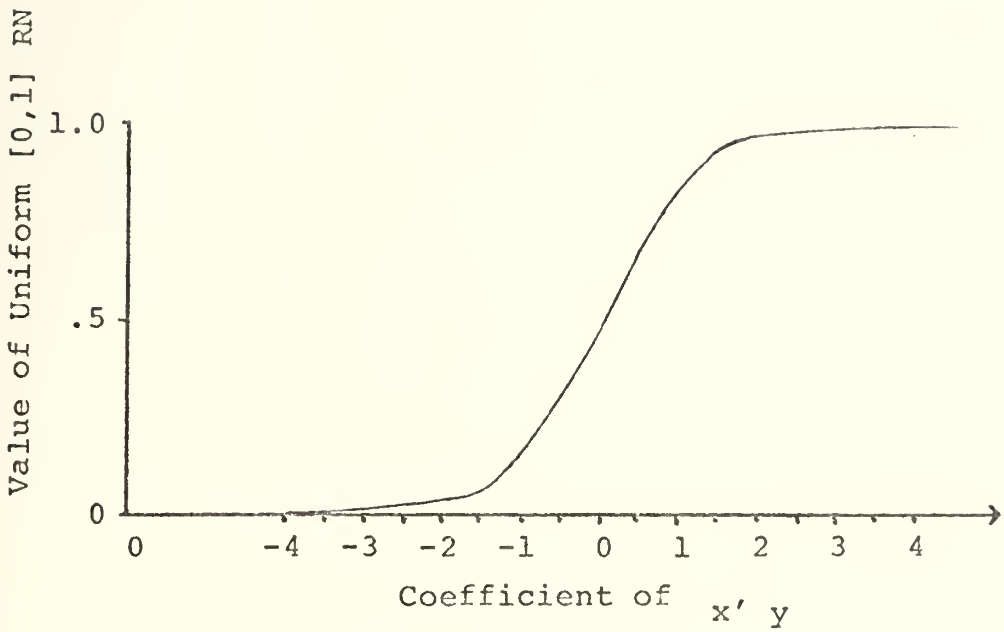

Figure 14. NORMAL (0,1) CDF

ENCLOSURE c. (Hit/Kill Probabilities: Figures and Tables) to APPENDIX A, TAB 2.

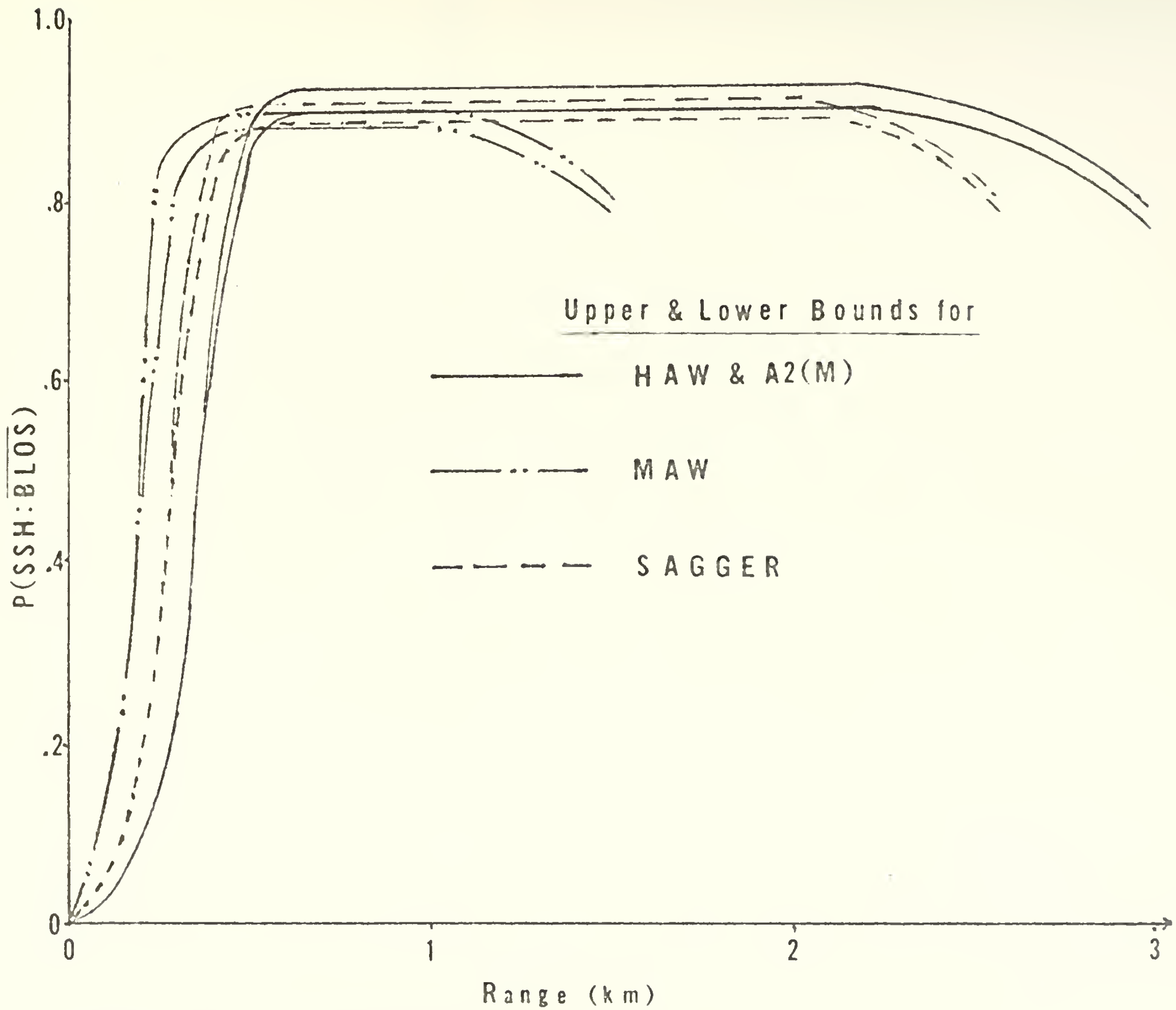

Figure 15. P(SSH:$\overline{BLOS}$) for ATGM.

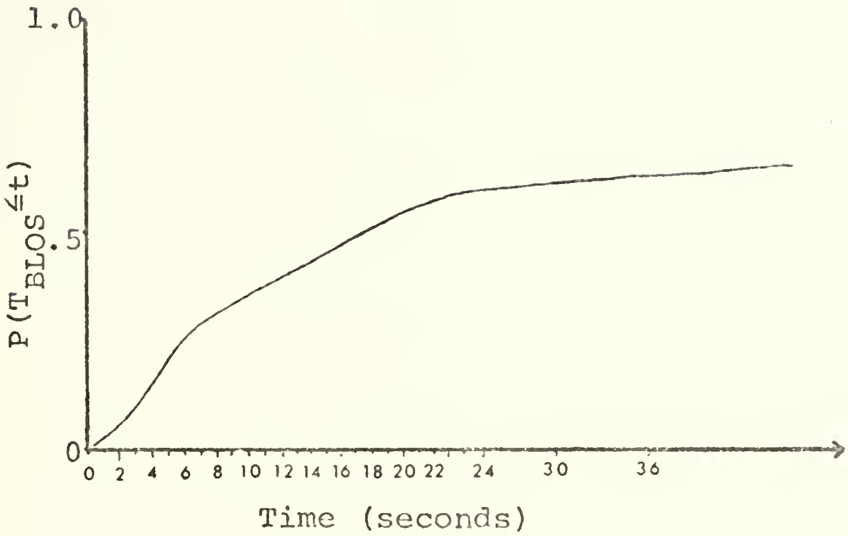

Figure 16. Cumulative Probability of Time to Break Line-of-Sight. [Ref. 18,p. 4-16 and 4-17]

KEY:

	P(SSH)	P(SSH: Miss)	v_{target}	Attack Angle
- - - - -	X		15 km/h	0°
—— ·· ——	X		15 km/h	45°, 90°
————	X	(X)	0,(15km/h)	0°
—x——x—	X	(X)	0,(15km/h)	45°, 90°
—— —		X	0	0°
· · · · · · ·		X	0	45°, 90°

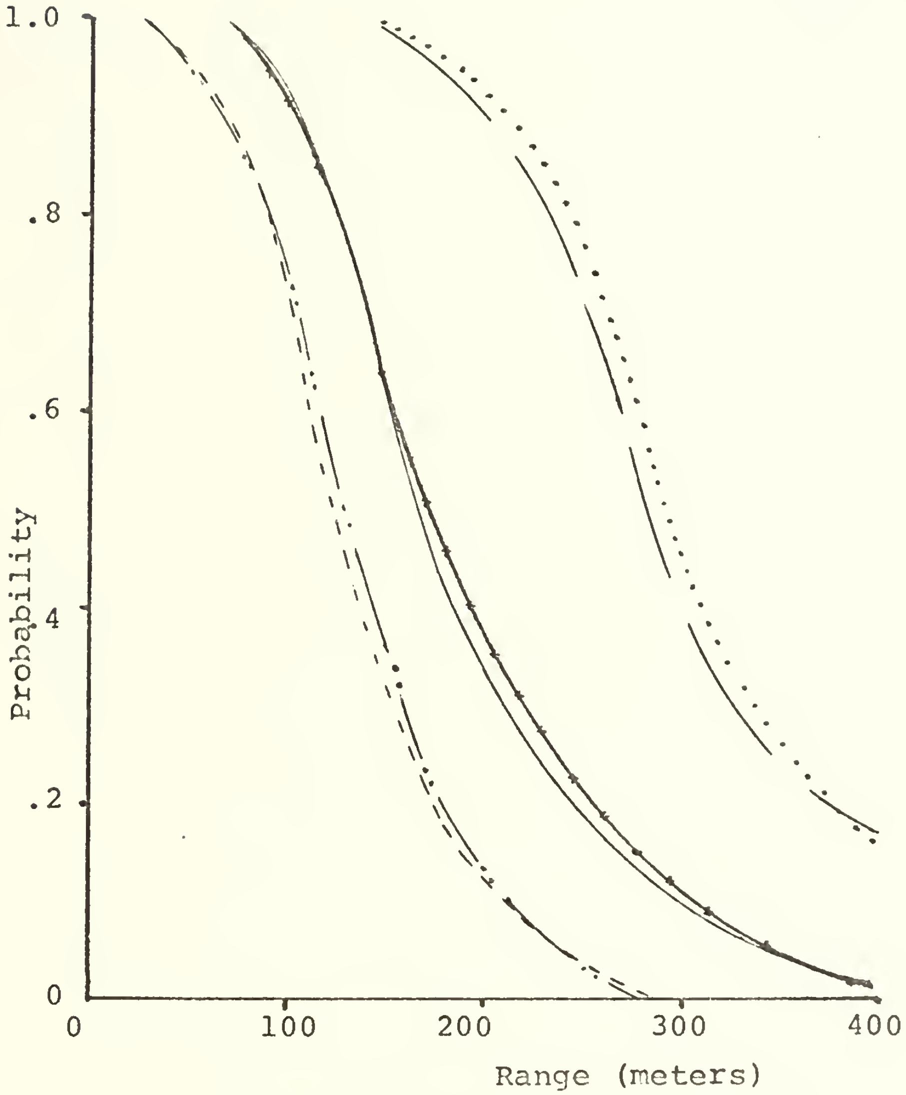

Figure 17. P(SSH) for LAW Firing at T-62. [Ref. 38,p. 11-13, 21, 64, 65, Table B-I, -II]

KEY:

	P(SSH)	P(SSH: Miss)	v_{target}	Attack Angle
	X		15 km/h	0°
	X		15 km/h	45°, 90°
	X	(X)	0,(15km/h)	0°
	X	(X)	0,(15km/h)	45°, 90°
		X	0	0°
		X	0	45°, 90°

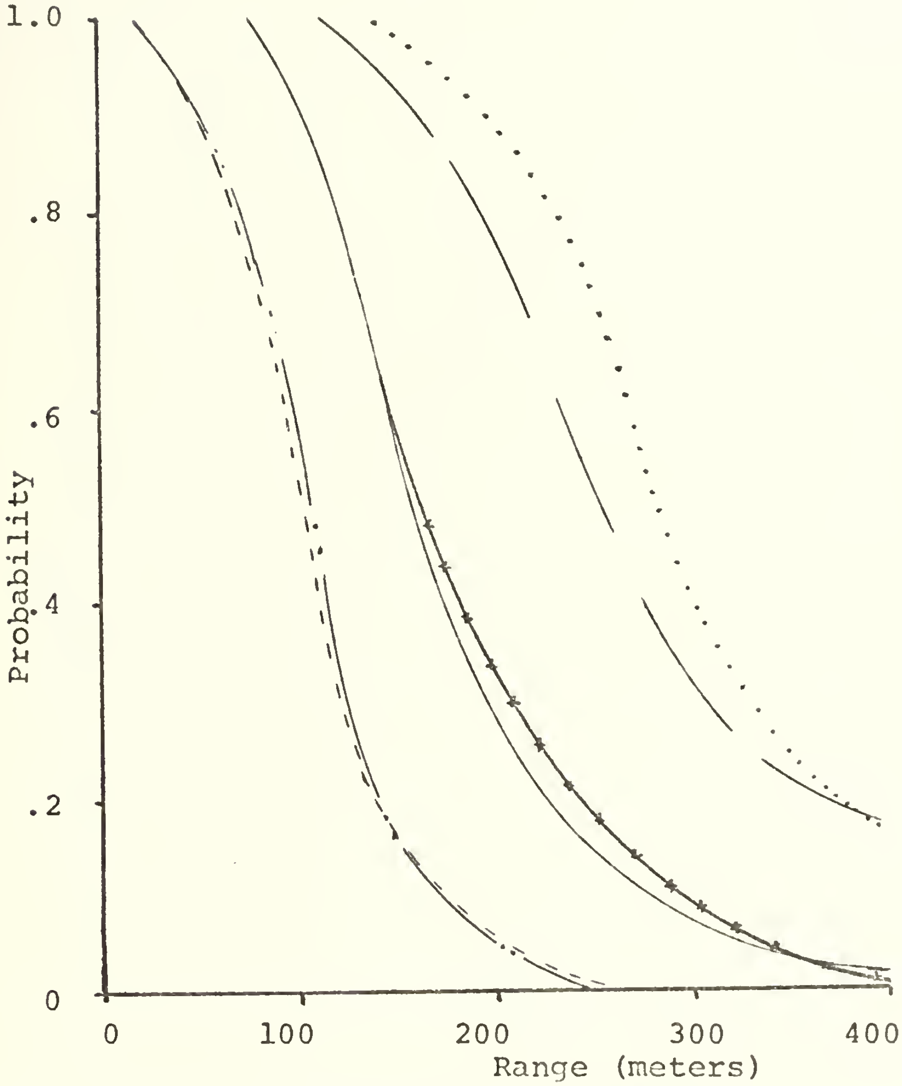

Figure 18. P(SSH) for LAW Firing at BMP-76.

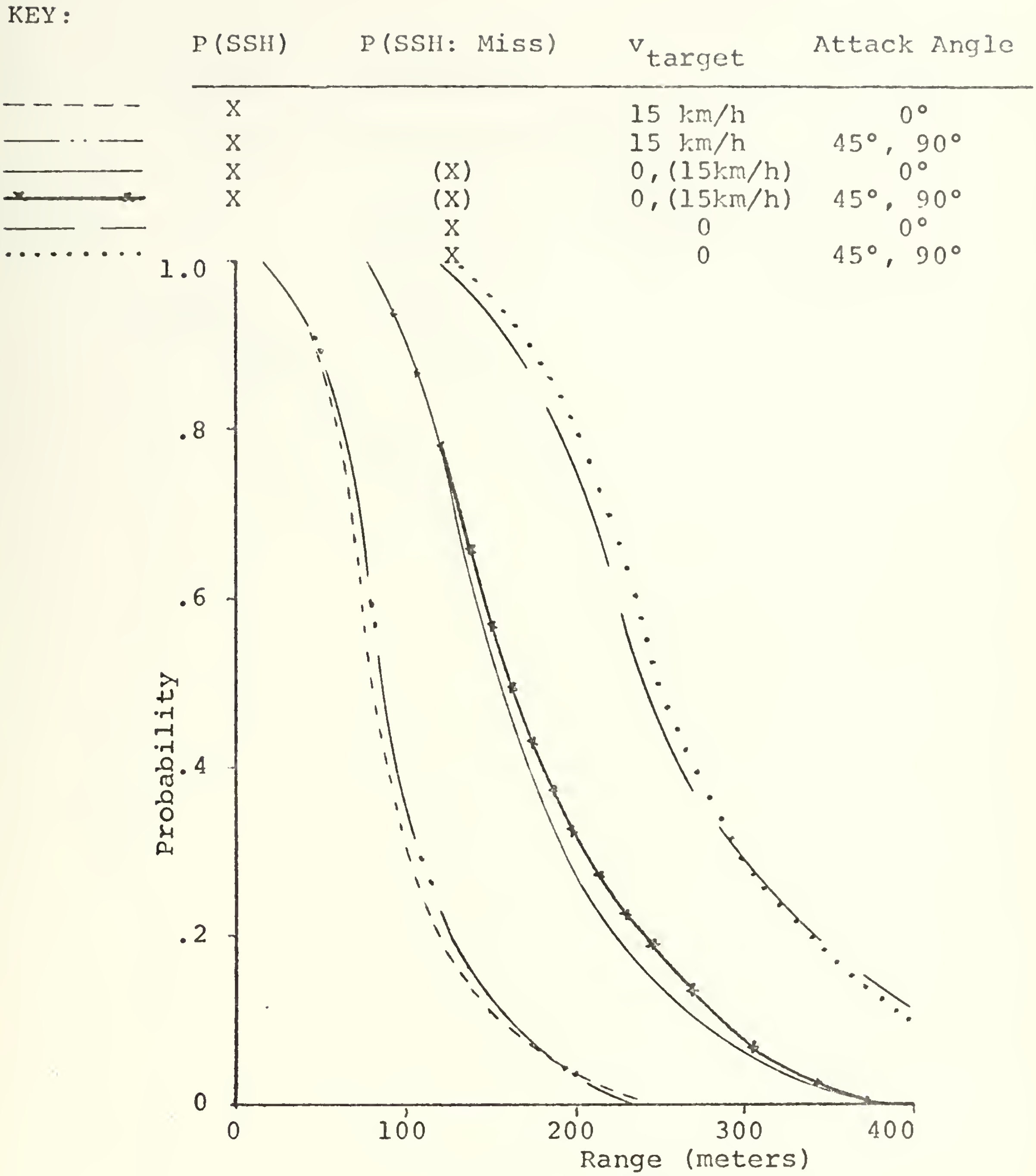

Figure 19. P(SSH) for LAW Firing at BRDM.

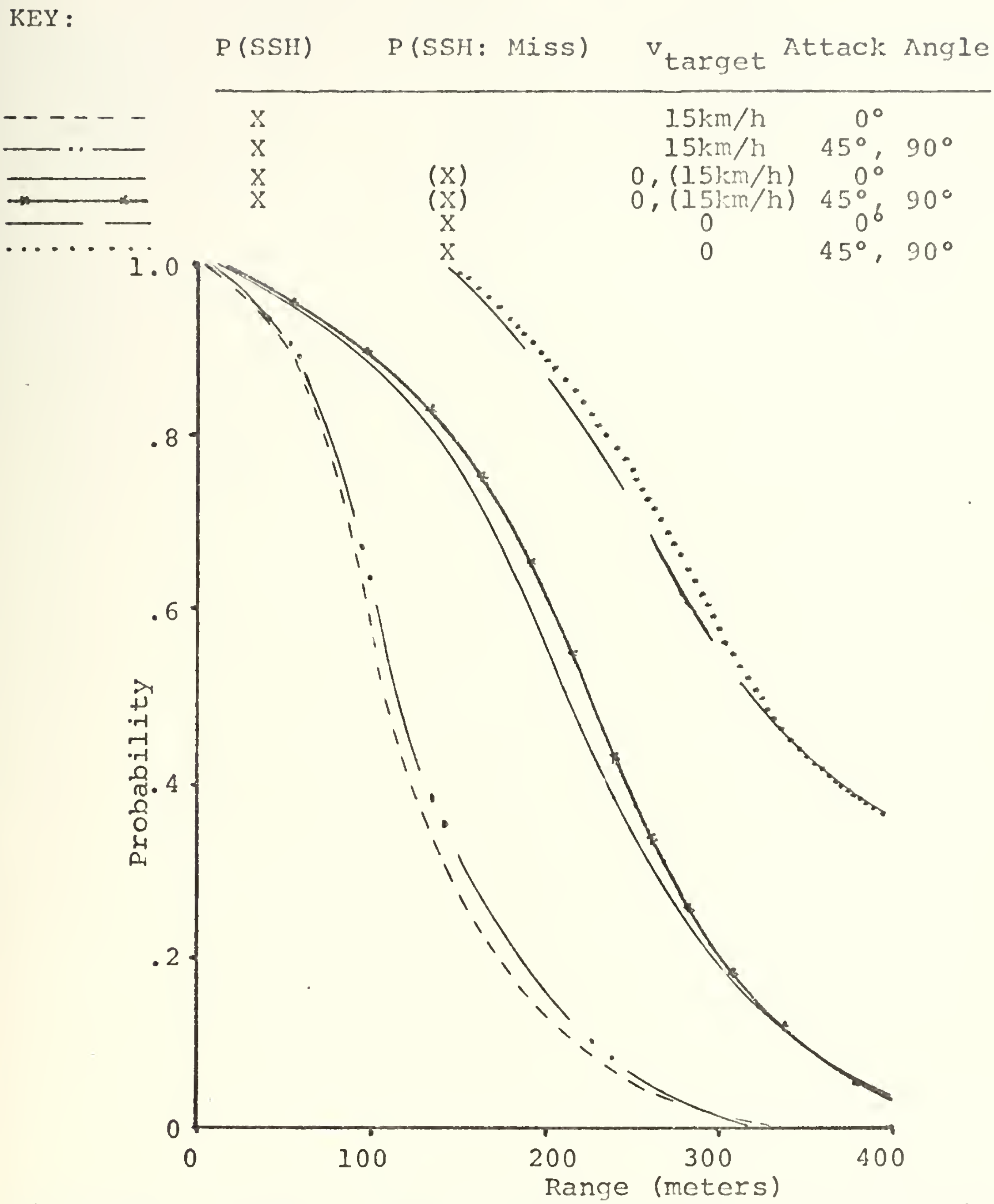

Figure 20. P(SSH) for M-79 Firing at T-62. [By assumption and Refs. 8 and 37]

KEY:

	P(SSH)	P(SSH: Miss)	v_{target}	Attack Angle
- - - - -	X		15 km/h	0°
—— ·· ——	X		15 km/h	45°, 90°
————	X	(X)	0, (15km/h)	0°
—*——*—	X	(X)	0, (15km/h)	45°, 90°
—— ——		X	0	0°
········		X	0	45°, 90°

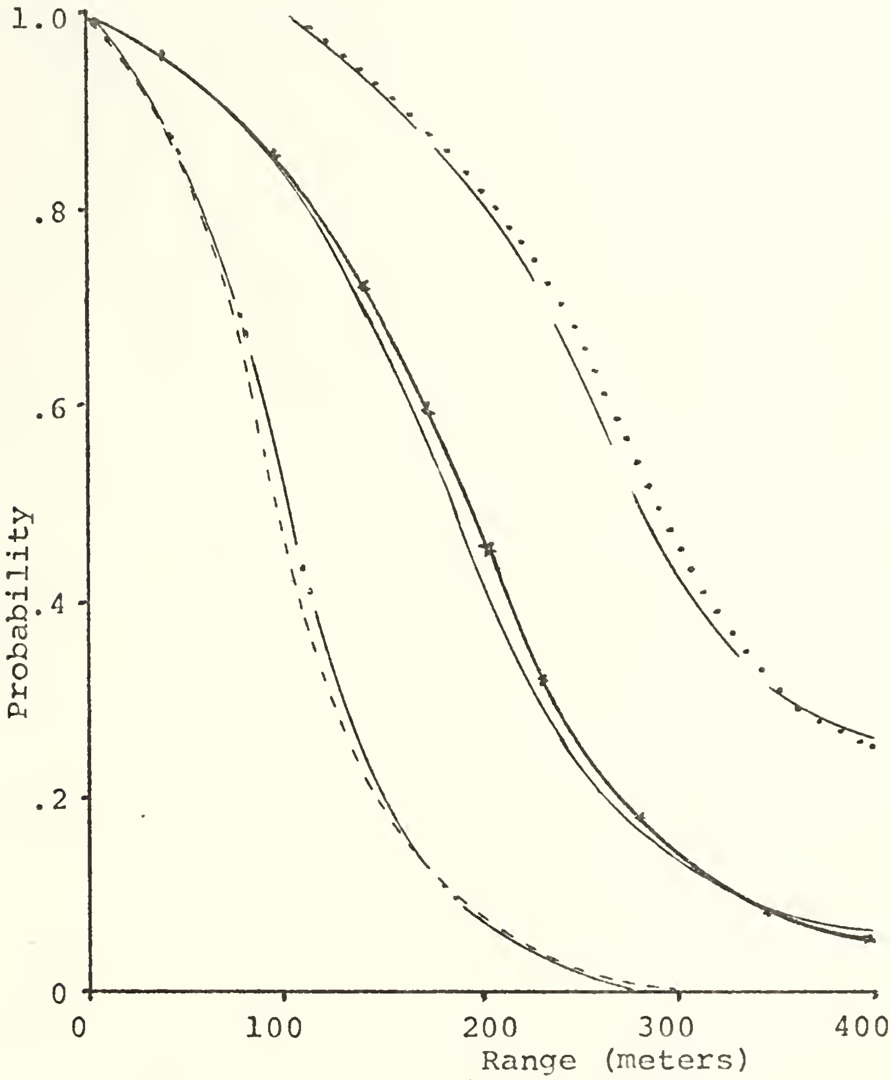

Figure 21. P(SSH) for M-79 Firing at BMP-76.

KEY:

	P(SSH)	P(SSH: Miss)	v_{target}	Attack Angle
- - - - - -	X		15 km/h	0°
——··——	X		15 km/h	45°, 90°
————	X	(X)	0,(15km/h)	0°
———	X	(X)	0,(15km/h)	45°, 90°
—— ——		X	0	0°
········		X	0	45°, 90°

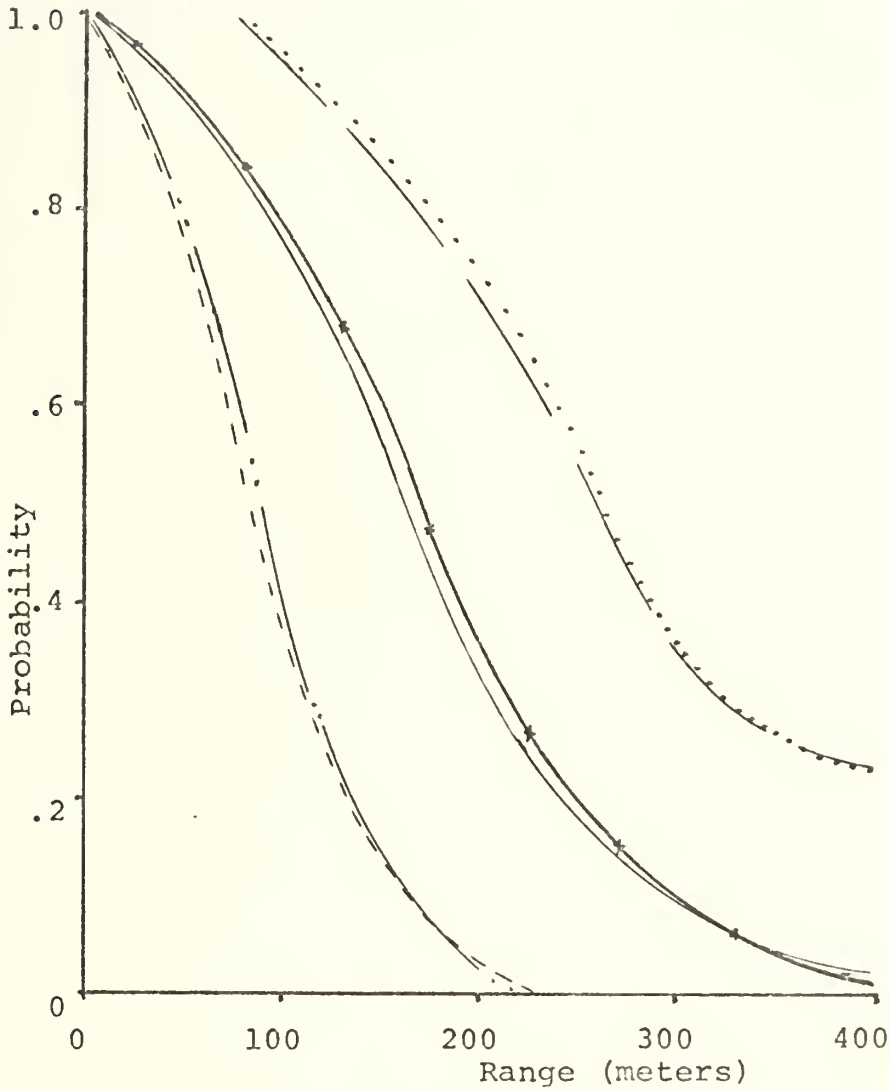

Figure 22. P(SSH) for M-79 Firing at BRDM.

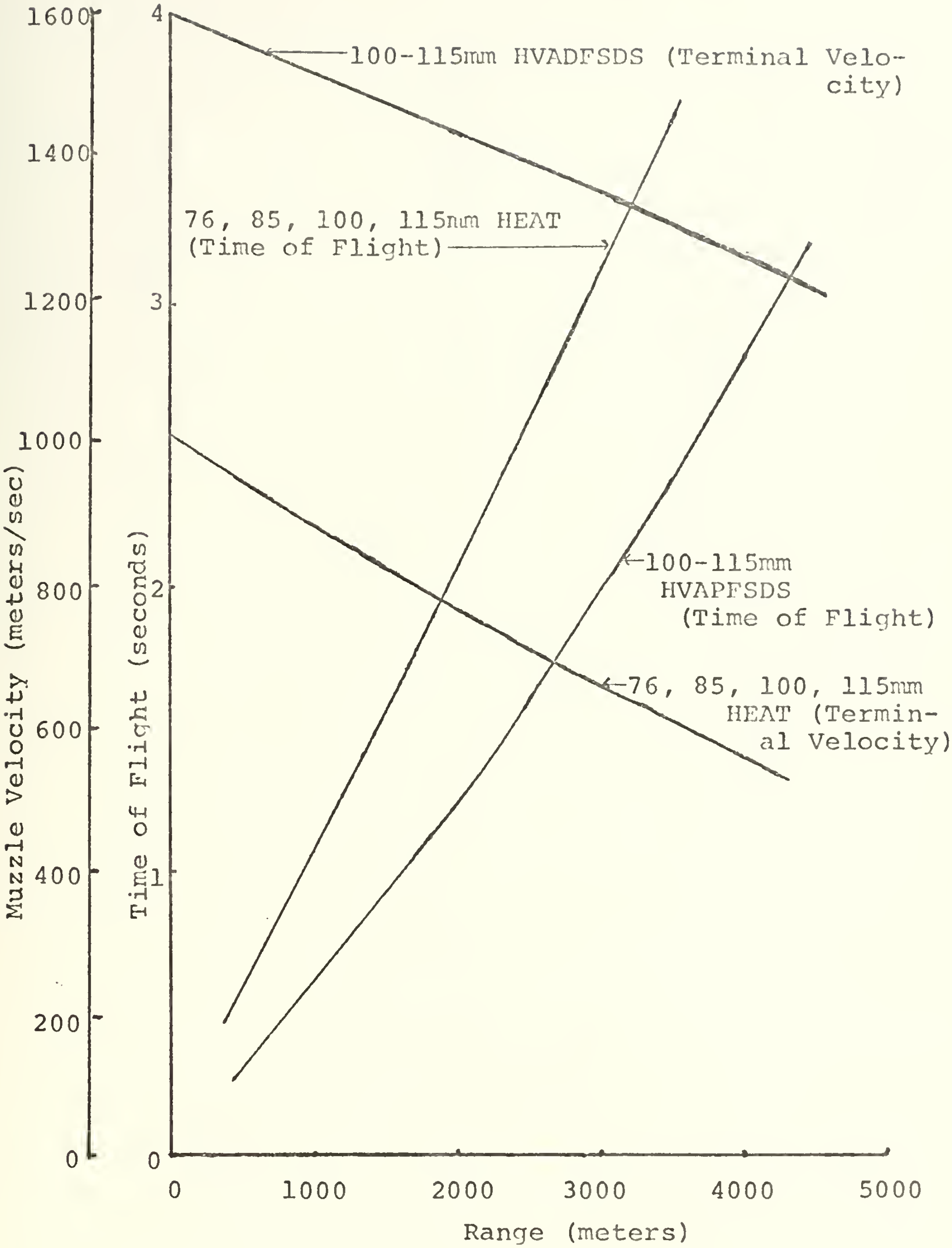

Figure 23. Projectile Times of Flight. [Refs. 17,22,39]

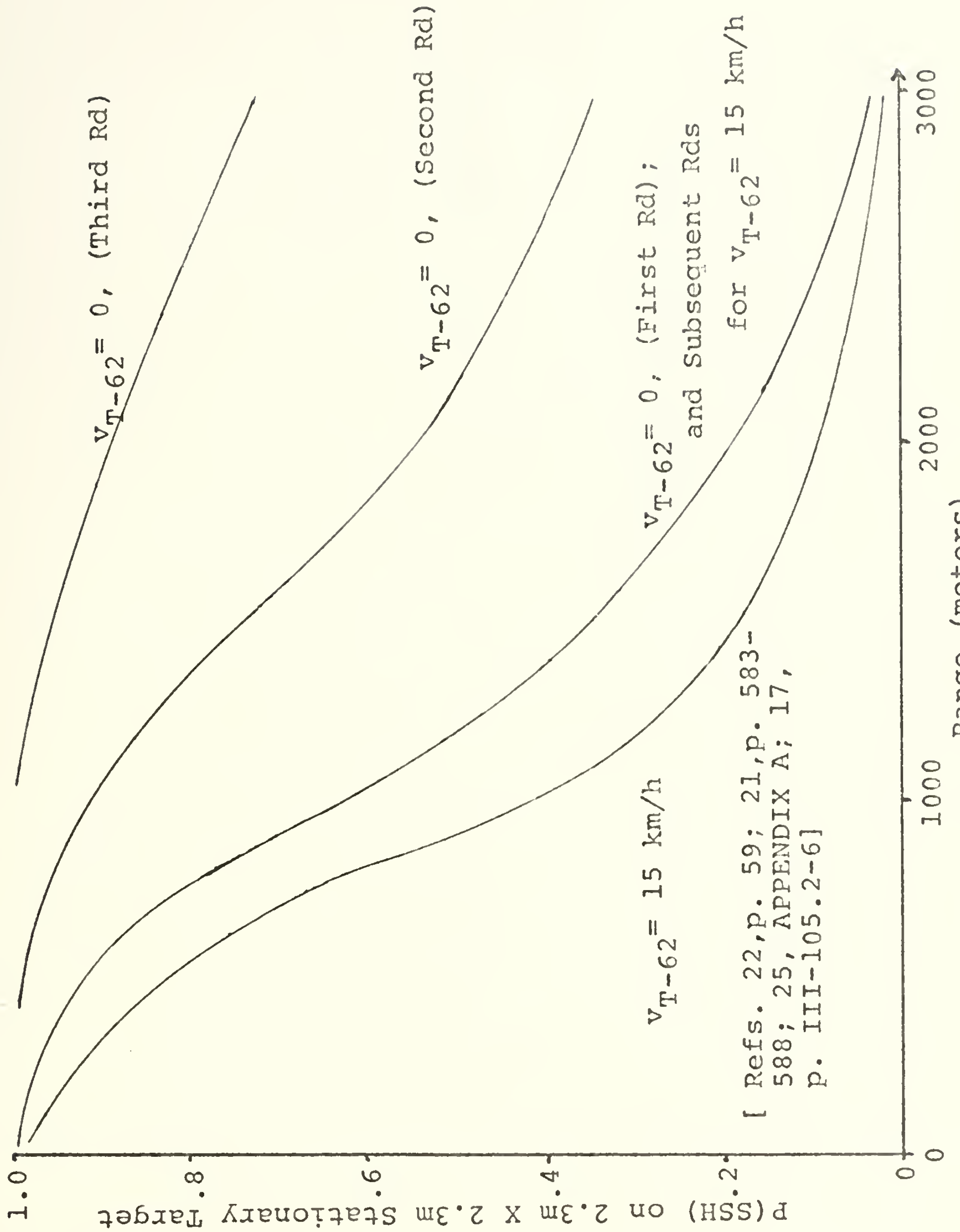

Figure 24. P(SSH) for 115mm HVAPFSDS

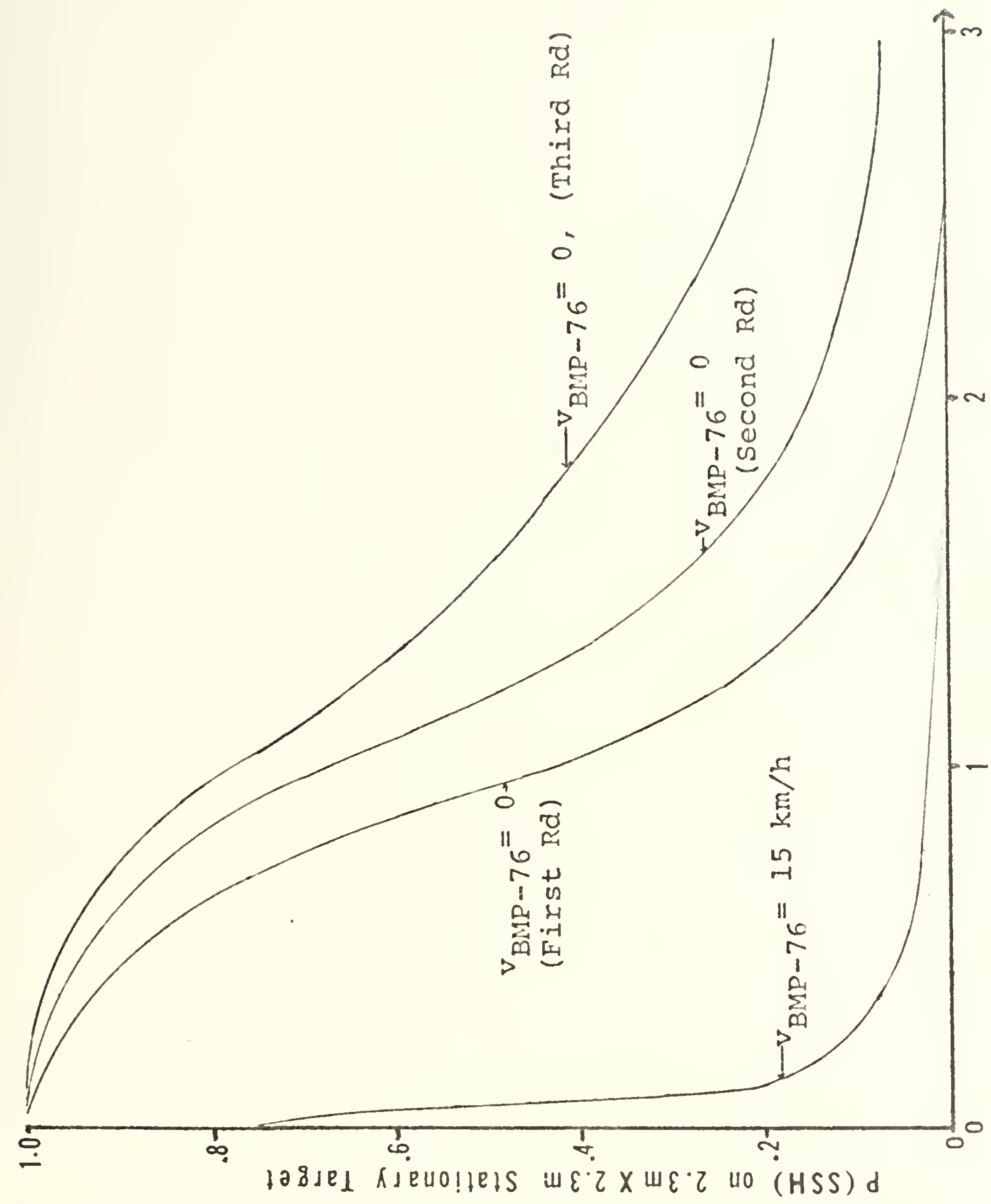

Figure 25. P(SSH) for 76mm FSHEAT [Refs. 24: Table 48; 25: APPENDIX A, p. 24; 39, p.364; 22, p. 64]

[Ref. 24,p. 79]

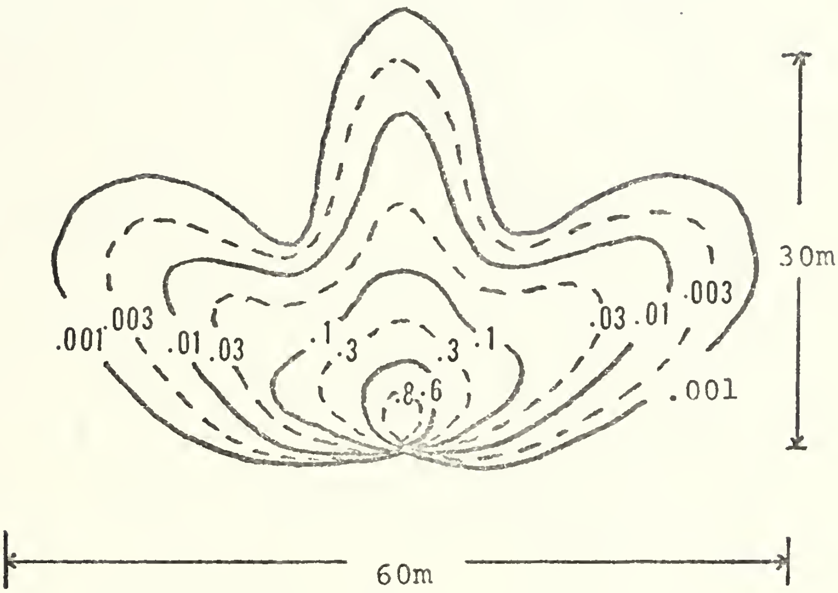

Figure 26. Casualty-Probability Contour Template 1.

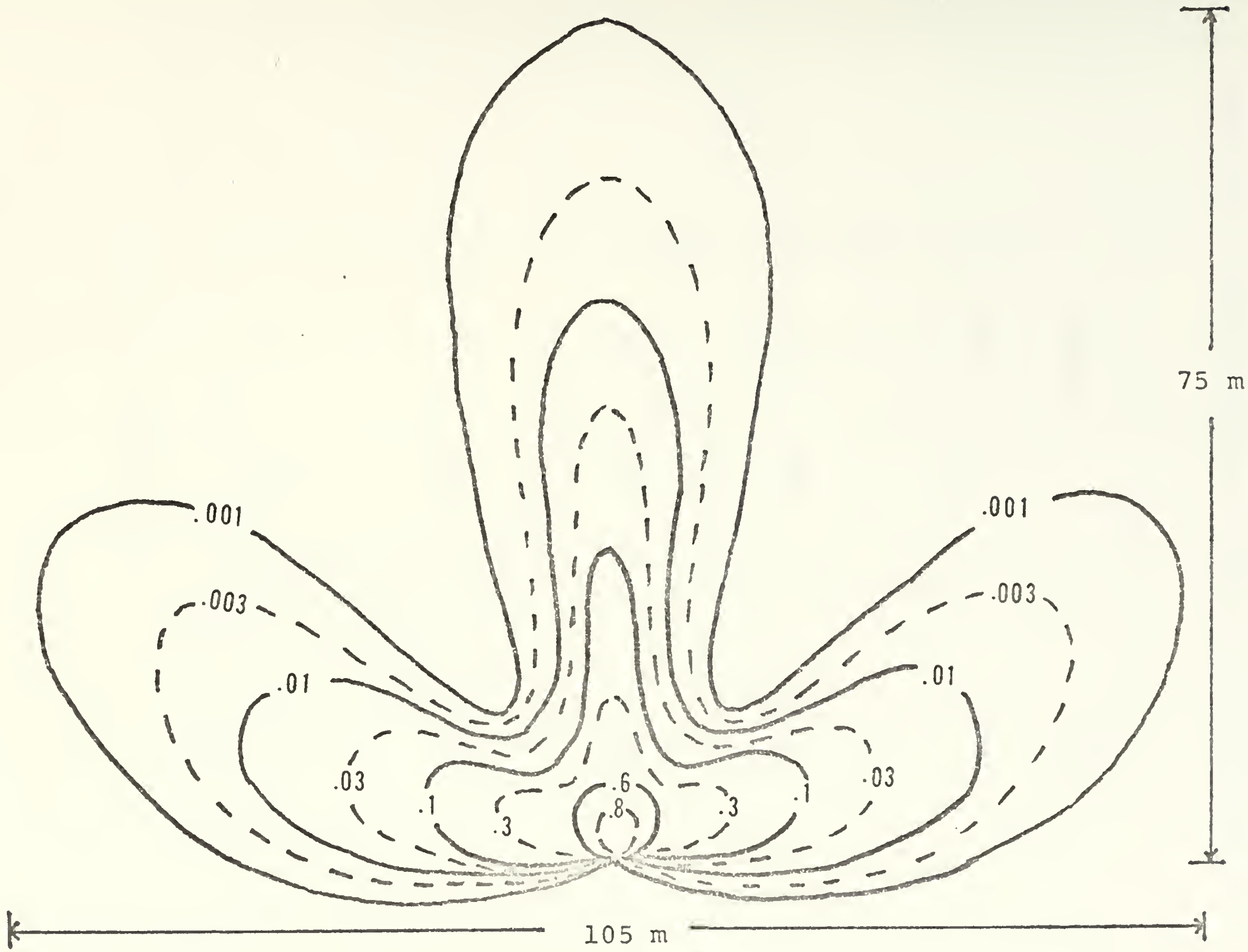

Figure 27. Casualty-Probability Contour Template 2. [Ref. 24, p. 78]

TABLE II.

ENGAGEMENT PROBABILITIES, GIVEN HIT PROBABILITIES

P(SSH)	P(E)
1.00 - .60	1.00
.59 - .50	.95
.49 - .35	.85
.34 - .25	.65
.24 - .00	.50

[Ref. 36, Table IV-2]

TABLE III.

P(KILL:SSH)

	KILL TYPE	T-62	BMP-76	BRDM	PT-76	SU-100 SU-122	M60A2	M113
MAW SAGGER A2(M)	M	.85	.95	.98	.92	.90	.85	.95
	F	.60	.75	.81	.65	.65	.60	.75
	C	.55	.72	.79	.61	.60	.55	.71
	MUF	.90	.98	1.0	.96	.95	.90	.99
HAW	M	.90	.97	.99	.95	.94		
	F	.65	.78	.80	.75	.75		
	C	.60	.76	.79	.72	.72		
	MUF	.95	.99	1.0	.98	.97		
100-115mm HVAPFSDS 500-2000m	M	.60.58	.90.88	.95.94	.80.78	.75.73	.65.63	.90.88
	F	.35.34	.60.58	.65.63	.40.39	.40.39	.40.39	.55.53
	C	.30.28	.52.49	.61.59	.30.28	.25.23	.35.33	.47.44
	MUF	.65.64	.98.97	.99.98	.90.89	.90.89	.70.69	.98.97
HE/HEAT ≤ 40mm	M	.15	.40	.45	.30	.25	.15	.40
	F	.05	.25	.30	.15	.10	.06	.25
	C	.03	.15	.25	.10	.05	.04	.17
	MUF	.17	.50	.50	.35	.30	.17	.48
HEAT: ≤ 90mm >40mm	M	.44	.85	.90	.75	.38	.45	.85
	F	.29	.65	.70	.35	.26	.30	.62
	C	.17	.55	.62	.20	.16	.20	.53
	MUF	.56	.95	.98	.90	.48	.55	.94
HEAT: > 90mm ≤ 122mm	M	.48	.92	.95	.80	.70	.48	.92
	F	.35	.70	.73	.50	.35	.35	.69
	C	.20	.66	.68	.35	.25	.25	.67
	MUF	.63	.96	1.0	.95	.80	.58	.94
HEAT: ≤ 152mm	M	.65	.98	.99	.88	.80		
	F	.47	.80	.90	.60	.50		
	C	.27	.78	.89	.47	.40		
	MUF	.85	1.0	1.0	.99	.90		

[Ref. 22, p.62; Ref. 39, p. 63]

TABLE IV.

AFV MAIN GUN ROUNR-TO-ROUND DISPERSION (HE/HEAT)

(σ_{x_i} = Deflection Standard Deviation; σ_{y_i} = Range Standard Deviation)

		R=350 m	R=700 m	R=1500 m
76 mm	σ_{x_i}	0	.3m	.3m
	σ_{y_i}	20m	20m	20m
85 mm	σ_{x_i}	0	.3m	.6m
	σ_{y_i}	35m	36m	37m
100 mm	σ_{x_i}	0	.3m	.3m
	σ_{y_i}	20m	20m	20m
115 mm	σ_{x_i}	0	.3m	.3m
	σ_{y_i}	20m	20m	20m

[Assumed values extrapolated from data in Ref. 24, p. 24, 27; Ref. 20, p. 34, 46]

ENCLOSURE d. (Algorithms for the "Monte Carlo"-Type Manual Game) to APPENDIX A, TAB 2.

ALGORITHM I. Determination of T_d and T_{be}.

ALGORITHM II. Determination of Engagement Times, Given Target Detected.

ALGORITHM III. ATGM Engagement of AFVs: Resulting P_k.

ALGORITHM IV. LAW and M-79 Engagement of AFVs: Resulting P_k

ALGORITHM V. AFV and AT Gun Main Gun Direct Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW): Resulting P_k.

ALGORITHM VI. AFV and AT Gun Main Gun Area Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW): Resulting P_k.

ALGORITHM VII. AFV and AT Gun Main Gun Direct Fire at Armored Targets: Resulting P_k.

ALGORITHM I (Determination of T_d and T_{be})

(See APPENDIX A, TAB 2, ENCLOSURE a for definitions of symbols.)

NOTE: For BLUE weapon systems, the first detections are assumed to be completed prior to t=0 in order to fire between t=0 and t=5 sec. In all cases, time to detect the same target, given the target was missed with a previous round from the same weapon, =0.

STEPS

1. If the system is a BLUE weapon, GO TO 4.

2. Judgmentally determine from the scenario diagram which targets have intervisibility with the system. If situation indicates that a visual detection of the BLUE target is likely, $T_d = T_{d_1}$: [(If system is a RED ATGM, $T_{be} = \max(T_{st}, T_d)$, use CDF Figure 2, and GO TO 5.) Otherwise, use CDF Figure 2, but use CDF for T_{d_1}. GO TO 5].

3. If the situation indicates a target hand-off is likely, for example, an individual tank following platoon leader's direction and engaging the same target, $T_d = T_{d_2}$: [If system is a RED ATGM, $T_{be} = \max(T_{st}, T_d)$ use CDF Figure 3, and GO TO 5.) Otherwise, use CDF Figure 3, but use CDF for T_{d_2} and GO TO 5.]

4. Judgmentally determine from the scenario diagram which targets have intervisibility with the system: [(For subsequent engagement of the same target for LAW and M-79, $T_{be} = T$; and $t_{be} = 4RN+4$; STOP.)
Otherwise, for first and subsequent engagements by other BLUE systems, $T_{be} = \max(T_d, T\ )$. Use CDF Figure 5, GO TO 5.]

5. Draw RN. On CDF figure assigned by previous step, enter vertical axis at value of RN. Project horizontally to curve of distribution. From point of intersection, project vertically downward to the time axis and read the realization of the random variable T_d or T_{be}, as appropriate, round to nearest tenth of a sec., STOP.

ALGORITHM II

(Determination of Engagement Times, Given Target Detected)

(See APPENDIX A, TAB 2, ENCLOSURE a, for definitions of symbols)

STEPS

1. Determine engagement type from scenario diagram, results of ALGORITHM I, and ENCLOSURE b, to APPENDIX A, TAB 2.

2. From ENCLOSURE b, determine the formulas for T_e, T_I, T_m, T_h, as appropriate. (For each engagement type, only one applies; that is, $T_e = T_l$ or T_m or T_h.)

3. Determine the number of random variables in the equation which must be calculated (for example, $\max(T_{st}, T_s)$ is considered to be one random variable and has one assigned CDF figure).

4. Draw a random number for each distribution of interest.

5. For each uniform random variable, T_j, use the linear transformation: Length of Interval (RN) + Value of Lower Bound = t_j. Round time (t_j) to nearest tenth of a second.

6. For other distributions wherein an assigned CDF figure is made, on the CDF figure assigned for that random variable, enter the vertical axis at the value of the RN. Project horizontally to curve of the appropriate distribution (some CDF figures have more than one distribution represented). From point of intersection, project vertically downward to the time axis and read the realization of the random variable of interest. Round value to the nearest tenth of a second.

7. Sum all realizations of the independent variables, as appropriate, to calculate the value of the realization of the dependent variable (the appropriate engagement time). STOP.

ALGORITHM III (ATGM Engagement of AFVs: Resulting P_k)

STEPS

1. From scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to nearest assigned or high priority target. Determine time to begin engagement process from ALGORITHM I. Determine time to engage (fire) from ALGORITHM II.

2. Calculate time of projectile flight (t_f) by ATGM type:

t_f = range to target/missile velocity. (See Enclosure b)

3. Determine $P(SSH:\overline{BLOS})$ from Figure 15, given range to target.

4. Determine P(Engagement: $P(SSH:\overline{BLOS})$) from Table II. Draw a random number. If RN > $P(E:P(SSH:\overline{BLOS}))$, record as no engagement, begin detection/engagement process again (determine from scenario diagram, earliest time to high enough $P(SSH:\overline{BLOS})$.[2] STOP

5. Determine P(Tgt breaks LOS: t_f and tgt speed) from Figure 16.[3]

6. $P(SSH) = P(SSH:\overline{BLOS})\ (1-P(BLOS))$, P(BLOS) calculated in Step 5.

7. Draw RN. If RN > P(SSH), missile misses; GO TO 8.[4] If RN≤P(SSH), missile hits; GO TO 9.

8. Calculate time to next engagement from ALGORITHMs I and II, record on TIME-HISTORY form, STOP.

9. Draw RN. Compare with P_k(M, F, C, MUF) values listed in Table III to determine type of kill, if any. Record results on TIME-HISTORY form. Calculate time to next engagement from ALGORITHMs I and II. Record results on forms for FORCE LEVELS (Tgt List). STOP.

---

[1] For first rounds of ambush, targets are assigned, hand-offs are completed, and first rounds are fired within the first five seconds (judgmentally determined times).

[2] For first rounds of ambush, $P(E:P(SSH:\overline{BLOS}))=1.0$, except for very low P(SSH) wherein judgement is used to determine P(E).

[3] Reference 18, pages 4-16 and 4-17.

[4] Assume negligible effect from near misses. Mobility and firepower suppression (time delays) may be judgmentally applied.

ALGORITHM IV (LAW and M-79 Engagement of AFVs: Resulting P_k)

STEPS

1. From scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to nearest assigned or high priority target. Determine time to begin engagement process from ALGORITHM I. Determine time to engage (fire) from ALGORITHM II.

2. Calculate time of projectile flight:
t_f = range to target/ projectile muzzle velocity (See Enclosure b.)[2]

3. Determine P(SSH), given range to target and aspect and speed of target, from Figures 17 through 22, as appropriate.

4. Determine P(E:P(SSH)) from Table II. Draw a RN. If RN $>$ P(E:P(SSH)), record as no engagement on TIME-HISTORY form, begin detection/engagement process again (determine from scenario diagram the earliest time to high enough P(SSH)).[2] STOP.

5. Draw RN. If RN $>$ P(SSH), projectile misses; GO TO 7.[3] If RN $\leq$ P(SSH), missile hits.

6. Draw RN. Compare with P_k(M, F, C, MUF) values listed in Table III to determine type of kill, if any. Record results on TIME-HISTORY form and FORCE LEVELS (Tgt List) forms.

7. Calculate time to next engagement from ALGORITHMs I and II, record on TIME-HISTORY form. STOP.

---

[1] For first rounds of ambush, targets are assigned, hand-offs are completed, and first rounds are fired within the first five seconds (judgmentally determined times).

[2] For first rouncs of ambush P(E)=1.0, except for very low P(SSH). In such cases, P(E) is judgmentally determined.

[3] Assume negligible effect from near misses. Mobility and firepower suppression (time delays) may be judgmentally applied.

ALGORITHM V (AFV and AT Gun Main Gun Direct Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW): Resulting P_k)

STEPS

1. From the scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to most likely target. Determine time to begin engagement process from ALGORITHM I. Determine time to engage (fire) from ALGORITHM II.

2. Calculate time of projectile flight, given range to target: Use Figure 23.

3. From the scenario diagram, determine which targets are within a 250 X 250m grid centered at the aim point/expected impact point at time of impact.

4. Assume targets have cover corresponding to vulnerable area presented by a prone man, facing the point of impact if still in firing positions. Otherwise assume vulnerable area presented by a crouching man. Place the base of each target on the grid, relative to the aim point.

5. Draw two RNs. Enter the vertical axis of CDF Figure 14 with the value of each RN and project horizontally to the curve of the distribution. From the point of intersection, project vertically downward to the $\sigma_{x,y}$ axis and read the values of the coefficients.

6. Multiply the values read by the appropriate σ_{x_i} or σ_{y_i} values found in TABLE IV: This gives the randomly selected center of projectile impact (-assuming an elliptic normal dispersion pattern). Place the appropriate Casualty-Probability Contour Template (Figure 26 or 27) on the point of impact, long axis oriented outward along the gun-target line. Figure 26 for prone personnel and Figure 27 for crouching personnel. For each target falling within the contours, note the appropriate P(SSK).

7. Scale each P(SSK) calculated in Step 6 by the following: Scale factor 1.0 for 115 mm; .9 for 100 mm; .8 for 85 mm; and .75 for 76 mm.

8. Draw a RN for each target covered by the template: If RN $>$ P(SSK)(Scale Factor), fragments miss the target; GO TO 9. If RN $\leq$ P(SSK)(Scale Factor), target hit (assumed killed). Judgmentally apply any material damage or restrictions on the unit due to position of the casualty (e.g., radio operator versus MAW gunner). Record results on TIME-HISTORY form and FORCE LEVEL (Tgt List) form.

9. Calculate time to next engagement from ALGORITHMs I and II, record on TIME-HISTORY form. STOP.

ALGORITHM VI (AFV and AT Gun Main Gun Area Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW): Resulting P_k)

STEPS

1. From the scenario diagram and TIME-HISTORY form, determine the range and direction to desired point of projectile impact (judgmentally applied).

2. Calculate time of projectile flight t_f from Figure 23, given range to impact point.

3. On the scenario diagram, determine which targets are within a 250 X 250m grid centered on the point of impact at time of impact.

4. On a 250 X 250m grid, randomly place each target found from Step 3, above:

Draw two RNs. Let W = width and depth of target at base, within the impact area. Let $x_t = (RN_1 - 0.5)(250 - W)$, let $y_t = (RN_2 - 0.5)(250 - W)$. [Ref. 40].

5. Place each target on the grid using the coordinates calculated in Step 3. (NOTE: Grid Center has coordinates (0, 0)).

6. Place the appropriate Casualty-Probability Contour Template (Figure 27 or 28)[1] on the center of the grid, long axis in the positive Y-direction. For each target falling within the contours, note the appropriate P(SSK).

7. Scale each P(SSK) calculated in Step 4 by the following: Scale Factor: 1 for 115mm; .9 for 100mm; .8 for 85mm; and .75 for 76mm.

8. Draw a RN for each target covered by the template: If RN $>$ P(SSK)(Scale Factor), fragments miss the target, GO TO 7. If RN $\leq$ P(SSK)(Scale Factor), target hit (assumed killed). Judgmentally apply any material damage or restrictions on the unit due to the position of the casualty. Record results on TIME-HISTORY form and FORCE LEVEL (Tgt List) form.

9. Calculate time to next engagement from ALGORITHMs I and II, record on TIME-HISTORY form. STOP.

---

[1]Assume targets have vulnerable area corresponding to prone man, facing the point of impact, if personnel still in firing position (use Figure 26). Otherwise targets have vulnerable area corresponding to a crouching man (Use Figure 27).

ALGORITHM VII (AFV and AT Gun Main Gun Direct Fire at Armored Targets: Resulting P_k)

STEPS

1. From the scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to most likely target. Determine the time to begin the engagement process from ALGORITHM I. Determine time to engage (fire) from ALGORITHM II.

2. Calculate the time of projectile flight, given range to target: Use Figure 24.

3. Determine P(SSH), given range to target and aspect and speed of the target, from Figures 24 and 26, as appropriate.

4. Determine P(E:P(SSH)) from Table II. Draw a RN. If RN$>$ P(E:P(SSH)), record as no engagement on TIME-HISTORY form; begin detection/engagement process again (determine from scenario diagram the earliest time to high enough P(SSH)). (Immediate fires which are part of counterambush procedures are judgmentally applied.) STOP.

5. Draw RN. If RN$>$P(SSH), projectile misses; GO TO 7.[1] If RN$\leq$P(SSH), projectile hits target.

6. Draw RN. Compare with P_k(M, F, C, MUF) values listed in Table III, to determine type of kill, if any. Record results on TIME-HISTORY form and FORCE LEVEL (Tgt List) forms.

7. Calculate time to next engagement from ALGORITHMs I and II, record on TIME-HISTORY form. STOP.

---

[1]Assume negligible effect from near misses. Mobility and firepower suppression (time delays) may be judgmentally applied.

ENCLOSURE e. (Algorithms for the Expected-Value Manual Game) to APPENDIX A, TAB 2.

ALGORITHM EV-I.	Determination of $\bar{t}_d$ and $\bar{t}_{be}$.
ALGORITHM EV-II.	Determination of Expected Engagement Times, Given Target Detection.
ALGORITHM EV-III.	ATGM Engagement of AFVs: Resulting P_k.
ALGORITHM EV-IV.	LAW and M-79 Engagement of AFVs: Resulting P_k.
ALGORITHM EV-V.	AFV and AT Gun Main Gun Direct Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW): Resulting P_k.
ALGORITHM EV-VI.	AFV and AT Gun Main Gun Area Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW): Resulting P_k.
ALGORITHM EV-VII.	AFV and AT Gun Main Gun Direct Fire at Armored Targets: Resulting P_k.
ALGORITHM EV-VIII.	Fractional Kill Determination.

ALGORITHM EV-I (Determination of $\bar{t}_d$ and $\bar{t}_{be}$)

(See APPENDIX A, TAB 2, ENCLOSURE a, for definitions of symbols)

NOTE: For BLUE weapon systems, the first detections are assumed to be completed prior to t=0 in order to fire between t=0 and t=5 sec. In all cases, time to detect the same target, given the target was missed with a previous round from the same weapon, = 0. Actual first firing times are judgmentally assigned.

STEPS

1. If the system is a BLUE weapon, GO TO 4.

2. Judgmentally determine from the scenario diagram which targets have intervisibility with the system. If the situation indicates that a visual detection of the BLUE target is likely, $\bar{t}_d = \bar{t}_{d_1}$: [If system is a RED ATGM, $T_{be} = \max(T_{st}, T_d)$, therefore, $\bar{t}_{be} = 3$ sec. STOP.) Otherwise, $\bar{t}_{d_1} = 2$ sec. STOP.]

3. If the situation indicates a target hand-off is likely, for example, an individual tank following platoon leader's direction and engaging the same target, $t_d = t_{d_2}$: [(If system is a RED ATGM, $T_{be} = \max(T_{st}, T_{d_e})$; therefore, $\bar{t}_{be} = 7.8$ sec. STOP.) Otherwise, $\bar{t}_{d_2} = 10$ sec. STOP.]

4. Judgmentally determine from the scenario diagram which targets have intervisibility with the system: [(For subsequent engagement of the same target for LAW and M-79, $T_{be} = T_\lambda$; therefore, $\bar{t}_{be} = 6$ sec. STOP.) Otherwise, $T_{be} = \max(T_d, T_\lambda)$. Therefore, $\bar{t}_{be} = 7.3$ sec. STOP.]

ALGORITHM EV-II (Determination of Expected Engagement Times, Given Target Detection)

(See APPENDIX A, TAB 2, ENCLOSURE a, for definitions of symbols)

STEPS

1. Determine engagement type from scenario diagram, results of ALGORITHM EV-I, and APPENDIX A, TAB 2, ENCLOSURE b.

2. From ENCLOSURE b, determine the formulas for T_e, T_l, T_m, or T_h, as appropriate. (For each engagement type, $T_e = T_l$ or T_m or T_h.)

3. Select the appropriate expected engagement time listed by that engagement type in ENCLOSURE b, according to weapon system. Record the expected engagement time determined on the TIME-HISTORY form. STOP.

ALGORITHM EV-III (ATGM Engagement of AFVs: Resulting P_k)

STEPS

1. From the scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to nearest assigned or high priority target. Determine expected time to begin engagement process from ALGORITHM EV-I. Determine expected time to engage (fire) from ALGORITHM EV-II.

2. Calculate time of projectile flight (t_f) by ATGM type:

t_f = range to target/missile velocity. (See APPENDIX A, TAB 2, ENCLOSURE b.)

3. Determine P(SSH:$\overline{\text{BLOS}}$) from Figure 15, given range to target.

4. Judgmentally determine advisability of engaging target (trade-off between revealing firing position, due to weapon signature, and possible low hit probability). If firing is aborted, determine the earliest time to a high enough P(SSH:$\overline{\text{BLOS}}$). STOP. Otherwise,

5. Determine P(BLOS), given t_f and target speed from Figure 16.[2]

6. P(SSH) = P(SSH:$\overline{\text{BLOS}}$) (1-P(BLOS)).

7. Select appropriate P(KILL:SSH) from Table III.

8. Multiply each P(KILL:SSH) by P(SSH) determined in Step 6. (For example, if from Table III, P(M-KILL:SSH) = .90, and P(SSH) = .50, then P(M-KILL) = .45.)

9. Determine the firer's firepower effectiveness (%F) from FORM C or D, as of the time of missile impact. Multiply the value determined by each of the P(KILL), by category of kill, and enter these results on FORM A, TIME-HISTORY.

10. GO TO ALGORITHM EV-VIII. (Fractional Kill Determination).

---

[1] For first rounds of the ambush, targets are assigned, hand-offs are completed, and first rounds are fired within the first five seconds (judgmentally determine firing times).

[2] Reference 18, pages 4-16 and 4-17.

ALGORITHM EV-IV (LAW and M-79 Engagement of AFVs: Resulting P_k)

STEPS [1]

1. From the scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to nearest assigned or high priority target. Determine expected time to begin engagement process from ALGORITHM EV-I. Determine expected time to engage (fire) from ALGORITHM EV-II.

2. Calculate time of projectile flight:
Assume constant velocities of 145 m/sec for LAW and 76 m/sec for the M-79 HEDP round. (Due to the short ranges involved).

3. Determine P(SSH), given range to target and aspect and speed of the target, from Figures 17 through 22, as appropriate.

4. Judgmentally determine advisability of engaging target (tradeoff between revealing firing position, due to weapon signature, and low hit probability). If firing is aborted, determine earliest time to high enough P(SSH). STOP. Otherwise,

5. Select appropriate P(KILL:SSH) from Table III.

6. Multiply each P(KILL:SSH), by category of kill, by P(SSH) determined in Step 5. (For example, if from Table III, P(M-KILL:SSH) = .90, and P(SS) = .50, then P(M-KILL) = .45).

7. Determine the firer's firepower effectiveness (%F) from FORM C or D, as of the time of firing. Multiply the value determined by each of the P(KILL), by category of kill, and enter these results on FORM A (TIME-HISTORY).

8. GO TO ALGORITHM EV-VIII. (Fractional Kill Determination).

---

[1] For first rounds of the ambush, targets are assigned, hand-offs are completed, and first rounds are fired within the first five seconds (judgmentally determine firing times).

ALGORITHM EV-V (AFV and AT GUN Main Gun Direct Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW): Resulting P_k)

STEPS

1. From the scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to most likely target. Determine expected time to begin engagement from ALGORITHM EV-I. Determine expected time to engage (fire) from ALGORITHM EV-II.

2. Calculate time of projectile flight (t_f) from Figure 23, given range to target.

3. From the scenario diagram, determine which targets are within a 250m X 250m grid centered at the aim point/expected impact point at time of impact.

4. Assume targets have cover corresponding to vulnerable area presented by a prone man, facing the point of impact, if the personnel still in firing positions. Otherwise, assume a vulnerable area equal to that for a crouching man [Ref. 24, pages 50 through 85].

5. Use Figure 26, CASUALTY-PROBABILITY CONTOUR TEMPLATE 1, for the first case in Step 4; and Figure 27, CASUALTY-PROBABILITY CONTOUR TEMPLATE 2, for the second case, as appropriate.

6. Place the base of the template on the origin of the 250m X 250m grid. For each target covered by a contour line, or between lines (interplate approximate values), record the appropriate P(SSK).

7. Scale each P(SSK) calculated in Step 6 by the following:
Scale Factor: 1.0 for 115mm, .90 for 100mm, .80 for 85mm, and .75 for 76mm. If any target within five meters of the aim point, GO TO 10.

8. Determine the firer's firepower effectiveness (%F) from FORM C or D, as the time of firing. Multiply the scaled P(SSK)'s by this value to get the corrected P(SSK)'s. Record these results on FORM A, TIME-HISTORY.

9. Degrade the firepower and mobility effectiveness of each target hit by twice the value of the corrected P(SSK).[1] Record the results as per ALGORITHM EV-VIII. STOP.

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[1]or 0%, whichever is the greater number. (Cannot get negative values).

10. Further correct for mean aim error by multiplying the P(SSK), <u>for each target within five meters of the expected aim point,</u> by the value of P(SSH) on a stationary 2.3 m X 2.3 m target, at that range. GO TO 8.

ALGORITHM EV-VI (AFV and AT GUN Main Gun Area Fire at Personnel and Ground-mounted, Crew-served Weapons (includes MAW); Resulting P_k)

STEPS

1. From the scenario diagram and TIME-HISTORY form, determine the range and direction to desired point of projectile impact. (This is judgmentally determined).

2. Calculate time of projectile flight (t_f) from Figure 23, given range to impact point.

3. From the scenario diagram, determine which targets are within a 250m X 250m grid centered at the aim point/expected impact point, at the time of impact.

4. Place the appropriate CASUALTY-PROBABILITY CONTOUR TEMPLATE (Figure 26 or 27)[1] on the center of the grid, long axis along the gun-target line. For each target covered by the contours, note the appropriate P(SSK).

5. Scale each P(SSK) calculated in Step 4 by the following:
Scale Factor: 1.0 for 115 mm, .90 for 100 mm, .80 for 85mm, and .75 for 76 mm.

6. Determine the firer's firepower effectiveness (%F) from FORM C or D, as of the time of firing. Multiply the scaled P(SSK)'s by this value to get the corrected P(SSK)'s. Record these results on FORM A, TIME-HISTORY.

7. Degrade the firepower and mobility effectiveness of each target hit by twice the value of the corrected P(SSK). Record the results as per ALGORITHM EV-VIII.

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[1] Assume targets have vulnerable area corresponding to a prone man, facing the point of impact, if personnel still in firing positions (use Figure 26). Otherwise, targets have vulnerable area corresponding to a crouching man (use Figure 27).

ALGORITHM EV-VII (AFV and AT GUN Main Gun Direct Fire at Armored Targets: Resulting P_k)

STEPS

1. From the scenario diagram and TIME-HISTORY form, determine possible target intervisibilities and range to most likely target. Determine the expected time to begin the engagement process from ALGORITHM EV-I. Determine the expected time to engage (fire) from ALGORITHM EV-II.

2. Calculate the time of projectile flight, given range to target using Figure 23.

3. Determine P(SSH), given range to target and aspect and speed of target or firer, from Figures 24 and 26, as appropriate.

4. Select appropriate P(KILL:SSH) from Table III.

5. Determine the firer's firepower effectiveness (%F) from FORM C or D, as of the time of firing. Multiply the value determined by each of the P(KILL), by category of kill, and enter these results on FORM A, TIME-HISTORY.

6. GO TO ALGORITHM EV-VIII (Fractional Kill Determination).

ALGORITHM EV-VIII (Fractional Kill Determination)

STEPS

1. Determine entering values of P(M-KILL), P(F-KILL), and P(C-KILL) from the appropriate weapon system engagement algorithm (ALGORITHMs EV-III through EV-VII).

2. From FORM C, for BLUE target, or FORM D, for RED target, determine the remaining target effectiveness immediately prior to round impact.

3. Degrade "%M" and "%F" by the entering P(M-KILL) and P(F-KILL) values. (For example, if the target had already been fractionally killed, and had "%M"=.80 then if the entering P(M-KILL)=.70, the new "%M" would =.80-(.80)(.70)=.80-.56=.24. Similarly, for "%F"= .70, and P(F-KILL)=.40, the new "%F"=.70(1-.40)=.42.) Record these new "%M" and "%F" values on FORM C or D, by the effective time.

4. Compute the amounts of M or F-Kill to be credited to the impacting round, by multiplying the corresponding category of P(KILL) by the "%M" or "%F" values on FORM C or D, as appropriate. Enter these amounts on FORM E or F (depending upon whether target is a BLUE or RED system).

5. In a similar manner to that stated above, the current level of catastrophic kill of each target is determined by adding to the previous value of C, found on FORM C or D, the amount (1-C)P(C-KILL). The amount added, in each case, is the value indicated on FORM E or F, as appropriate. The current value of C is then recorded on FORM C or D, by the effective time of occurrence.

6. At the end of the game, the exchange ratios and loss rates are determined from the totals of the fractional kills recorded on FORMs C through F; and are then transferred to FORM B, FORCE LEVEL (Tgt List), as initial values for the next ambush iteration.

7. As necessary, return to the immediately previous algorithm for completion of any remaining steps. Check scenario diagram and TIME-HISTORY form to determine next critical event. STOP.

TAB 3 (Analysis of Exercise Results) to APPENDIX A

Within this tab are an analysis of one iteration of the manual war game employing the "Monte Carlo" approach, and one wherein an expected-value approach was employed.

The former approach was used primarily to gain insight into the validity of the initial assumptions and derivation of more, in order to finalize the scenario and computational framework for the expected-value approach. The analyses of both include extracts of the time-history of engagements, and sample records of the engagements indicating the procedures employed.

The reader is cautioned to not attempt any direct comparison of the battle results, as some of the critical event time distributions were altered following additional research, during the development of the expected-value approach.

ENCLOSURE a (Analysis of the "Monte Carlo"-Type War Game Results) includes a listing of observations relative to the simplifying modeling assumptions and tactics employed.

ENCLOSURE b (Analysis of the Expected-Value War Game Results) includes the discussion of a simple methodology for determining force exchange ratios and weapon system loss rates.

ENCLOSURE a. (Analysis of the "Monte Carlo"-Type War Game Results) to APPENDIX A, TAB 3.

A listing of the major game results is recorded in TABLE V, with the initial three kills reflected on the attached sample TIME-HISTORY form, FORM A. Note that each engagement is recorded twice - once at the time of weapon system firing, wherein the calculated projectile impact time (t_i) signals the placement of the engagement within the sequencing of critical events; and, once at the time of impact when the results are computed.

An example of judgmental application of the algorithms is shown on FORM A, at t= 5.1 seconds. Here, regardless of P(SSH) for the M-79, since the HEDP round had been fired at t= 1 sec and could not be guided in flight, it was caused to be a miss. Note that the MAW, M_3, had, at t= 3.5 sec, achieved a mobility-kill on the same target, thus, by assumption, effectively stopping its forward motion.

The high kill rate for the MAWs was attributed to the short ranges of engagement effectively precluding line-of-sight-breaking evasive maneuvers by the target AFVs.

The counterambush tactic which was examined for the BMP-76s was to fire HEAT ammunition at the mech infantry platoon positions, while attempting to close with same. This produced negligible results due to the relatively slow rate of fire and low P(SSH), since the 76mm smoothbore gun is not stabilized.

TABLE V

THE "MONTE CARLO" WAR GAME:
SIGNIFICANT ENGAGEMENT RESULTS

TIME (sec)	WPM (#)	TGT (#)	RESULTS
2.1	MAW(M_1)	T-62 (2c)	Catasgrophic Kill
3.5	MAW (M_2)	T-62 (1c)	Catastrophic Kill
3.5	MAW (M_3)	BMP-76(11a)	Mobility Kill
11.1	M60A2(T_3)	T-62 (2a)	Catastrophic Kill
14.8	MAW (M_3)	BMP-76(11b)	Mobility Kill
15.8	MAW (M_2)	T-62 (1b)	Catastrophic Kill
22.4	BMP-76(13a)	LAW (L_1)	Personnel Kill
27	MAW (M_3)	BMP-76(12c(M))	MUF-Kill (Tgt suppressed for duration of ambush)
28.1	M60A2(T_2)	T-62 (2b)	Tgt hit with minor damage (RN MUF)
29.8	HAW (H_1)	T-62 (3c)	Catastrophic Kill
31.3	M60A2(T_4)	T-62 (2b)	Mobility Kill (Tgt stationary from t= 28.1 sec)
33.3	T-62 (3a)	HAW (H_2)	Minor damage (RN MUF)
40.3	BMP-76(23c)	HAW (H_2)	Added minor damage (RN MUF)
41.9	M60A2(T_3)	BMP-76(22c(M))	Catastrophic Kill
43.9	HAW (H_1)	T-62 (3b)	Catastrophic Kill

TIME (sec)	WPM (#)	TGT (#)	RESULTS
49.9	M60A2(T_2)	BMP-76(21a)	Catastrophic Kill
50.6	BMP-76(23a)	HAW (H_1)	Catastrophic Kill (H_1 had started to disengage at t= 50 sec.)
51.5	85mmATAP(85d)	M-79 (G_3)	Personnel Kill
55.7	M60A2(T_1)	T-62 (6)	Catastrophic Kill
56	BMP-76(21b)	M60A2(T_5)	Mobility Kill (implies probable loss of vehicle given situation)
56.5	M60A2(T_4)	BMP-76(26)	Catastrophic Kill
156	T-62 (1b)	3rd Sqd APC	Catastrophic Kill

EXTRACT FROM: TIME-HISTORY for Mech Inf Plat AT Ambush; 2 sec-

t= (a)	WPN # (d)	TGT # (f)	RANGE (g)	RDS-OH/ EXPND (h)	TYPE ENGAGEMENT (i)	t_f (j)	t_i (k)	P_{ssh} (l)	P_k (M,F, $_{C,MUF}$) (m)	RESULTS (n)	t_e (o)	t_1 $t_{m,h}$ (p)
2	M_3	11a	300	3/1	1DSM(1)	1.5	3.5					
2	T_3	2a	2030	13/1	1DSM(1)	9.1	11.1					
2.1	M_1	2c	425	Impact	1DSM(1)			.882 RN= 859	RN=539 C-KILL= .55	Catastrophic Kill	10	t_1= 12.1
2.2	L_2	1c	260	Impact	1DSM(1)			.04- RN= 653		Miss	6	t_m= 8.2
***	*****	*****	*****	*****	*****	**	**	**	*****	*********	**	**

FORM A

Since the MAW gunner is particularly vulnerable due to a need to maintain his sight on the target throughout missile flight, it was felt that a better suppressive effect might possibly be created by having the BMP-76s fire their coax-MGs. This system also has a relatively low hit probability for any one round or single short burst [Ref. 41], but the rate of fire allows good area coverage, and a more constant suppressive effect (given that the gunner has some form of missile firing signature on which to sight).

Another judgmental aspect of the game was the decision to fire the LAW and M-79 at ranges resulting in very low P(SSH)s. In reality, the gunners would probably not have fired (and revealed their firing positions) but have waited until assured a higher hit probability. The trade-off becomes complicated when they have waited too long and find themselves being maneuvered upon and decisively engaged.

The fact that the BLUE forces sustained little in the way of significant casualties until after the mech platoon started to withdraw implies that there is a "safe" time caused by the shock and confusion created by the surprise of the ambush. The length of such a time interval is of major concern to the ambush planner. It was seen that when the HAW and M60A2s attempted to remain in firing positions long enough to complete the withdrawal of the mech platoon, that significant losses began to be felt. The question then becomes one of, "Should the infantry withdraw sooner?" or, "Should the HAW and

M60A2 displace to new firing positions after having fired one, or at most two missiles?" These questions are not answered here, but it is noted that the answer is greatly scenario-dependent. (See ENCLOSURE b, this tab, for further discussion on this point.)

An obvious example of a type result from such a choice of tactics is the action recorded at t= 156 seconds. Here, the T-62, 1b, in attempting to close with the withdrawing 2nd Squad, encountered the 3rd Squad, mounted and moving in its armored personnel carrier. The complete vulnerability of the APC to the tank is apparent given that the APC is armed with only a Cal. .50 machine gun. Here, the BLUE tanks were not in a position to provide continuous overwatch.

The above-mentioned situation suggests an additional, and often voiced, trade-off problem; that being, an optimal placement of vehicles, range of engagement, and time of disengagement (withdrawal). To be safe from being maneuvered on in a short period of time, the mech platoon must either be at extreme ranges, have very favorable terrain conditions, or withdraw sooner.

The first alternative negates the effect of the LAW and M-79 and is, therefore, bad from the standpoint of maximum effective use of available, antiarmor weapon systems. The second alternative is better, but such terrain, affording obstacles to the RED force, and providing immediate covered and concealed withdrawal routes, is likely to be recognized as such by the enemy, with resultant modifications in his approach. The third alternative needs to be examined in

greater detail, in light of the weapon system attrition rates effected over set time intervals. A first cut at this is discussed in ENCLOSURE b to this tab.

ENCLOSURE b. (Analysis of the Expected-Value Manual War Game Results) to APPENDIX A, TAB 3.

The statement of a few caveats relative to the expected-value methodology, as herein employed, are appropriate. This procedure, as configured, must be exercised with caution since an error in the computation of fractional kills or residual firepower effectiveness for a system will affect all future interactions (values of fractional kills resulting from engagements with other systems). This is especially the case when both firer and target have undergone multiple engagements, and, consequently, are neither at full effectiveness at the time of the engagement in question. Additionally, care must be taken to check the cumulative catastrophic kill level (C) of a BLUE system before allowing it to continue its automatic event sequencing, since, if it fires at a target after having been itself at least 50% catastrophically killed, it will have violated Procedure 10, of TAB 1 (The Manual War Game: Procedures and Rules) to APPENDIX A.

Also, a clear perception of the progress of the battle is required to realistically play the direct and area fire of AFVs and AT guns at personnel targets. In this line, great flexibility of choice of aim/expected impact points is afforded.

Relative to the iteration which was run, as the battle progressed to later stages, wherein all of the RED weapon systems which had targets within range engaged same, the expected-value game quickly

became a very time consuming exercise. For this reason, the battle was terminated at a point which clearly indicated the trend of events, as the BLUE system loss rate began to become significant, indicating the non-feasibility of BLUE continuing to employ the same tactics. To a degree, this point was predictable since the "Monte Carlo" approach had indicated it would happen. Intuitively, it holds also, as there is a point when the ambusher loses the effect of surprise and the numerically superior ambushed force begins to effectively react.

Basically the same scenario was played for the expected-value game as was previously exercised, with the exception of BMP-76 main gun fire. In the expected-value approach, the BMP-76s halted to fire at all long-range armored targets, and fired on the move at all short and medium range personnel and ground-mounted, crew-served weapons, including MAW.

A complete listing of TIME-HISTORY forms showing the progress of the battle is available on request; but it will suffice here to show the final system effectiveness levels as of game termination, the breakdown of losses by weapon system type, and a sample TIME-HISTORY sheet. The record forms have little meaning in isolation, but in conjunction with each other give a fairly clear picture of how the battle progressed.

The enclosed TIME-HISTORY form represents the same basic time phase of the battle as indicated in ENCLOSURE a, to this tab.

EXTRACT FROM: TIME-HISTORY for Mech Inf Plat AT Ambush; 2.1 sec- 9.6 sec;

t= (a)	WPN # (d)	TGT # (f)	RANGE (g)	RDS-OH/ EXP (h)	TYPE EN- GAGEMENT (i)	t_f (j)	t_i (k)	P_{ssh} (l)	P_k (M,F, C, MUF) (m)	RESULTS (n)	t_e (o)	t_1 $t_{m,h}$ (p)
2.1	M_1	2c	425	Impact	1DSM(1)			.864	.85,.60, .55,.90	M=.734,F= .518,C=.475 MUF=.778	19.5	t_1= 21.6
2.5	M_2	1c	300	Impact	1DSM(1)			.872	.85,.60, .55,.90	M=.74,F=.523 C=.48, MUF=.785	19.5	t_1= 22
3	T_4	2a	2020	13/1	1DSM(1)	9	12					
3	T_5	3c	2075	13/1	1DSM(1)	9.3	12.3					
3.5	M_3	11a	300	Impact	1DSM(1)			.872	.95,.75, .72,.98	M=.829,F=.66 C=.628	19.5	t_1= 23
4	H_1	3c	2000	6/1	1DSM(1)	6.7	10.7					
5	H_2	3b	1990	6/1	1DSM(1)	6.6	11.6					
9.6	T_1	2c	1920	Impact	1DSM(1)			.607	.85,.60, .55,.90	M=.137,F=.18 C=.175,MUF= .546;Cum.C= .65	23.2	t_1= 32.8

FORM A

Note the use of the dual recording of engagements with the checks made in column k indicating that these firings have been recorded a second time and the resulting fractional kills recorded. The kills scored in column n incorporate the residual levels of effectiveness resulting from previous engagements by both firer and target.

Additional markings in column p opposite the events at t= 2.1 and t= 2.5 seconds show that the subsequent engagements of new targets were terminated at 16.3 and 18.3 seconds of the battle, respectively, due to both M_1 and M_2 having reached levels of catastrophic kill equal to, or in excess of, 50%.

The enclosed FORM B, FORCE LEVELS (Tgt List), shows the residual levels of effectiveness at the time of game termination. In this case, termination occurred prior to entrance into the battle of the 85 mm ATAP systems in the RED battalion second echelon. Here, the t_{in} represents the time a system begins to react to the situation and actively seeks a target. Theoretically, the residual effectiveness levels at the end of one iteration of the game would act as inputs to the next iteration.

The results of significant engagements are recorded on the forms C through F. FORMs C and D indicate the residual mobility and firepower effectiveness of the indicated system immediately following the last engagement in which losses were incurred. The cumulative catastrophic kill level to that time is also recorded. FORMs E and

FORCE LEVELS (Tgt List)

WPN NO.	t_{in}	t_1	%M	%F	%C
M_1	-30	0	0	0	80.8
M_2	-30	1	0	0	83.3
M_3	-30	2	54.6	54.6	23.8
L_1	-30		100	100	0
L_2	-30		100	100	0
***	***	***	******	******	******
T_4	-30	3	22.5	45.4	50
T_5	-30	3	10.3	40.6	53.8
***	***	***	******	*******	*******
6	5	20.5	47	62.6	34.3
1a	0.5	16	100	100	0
1b	2.5	18	61.6	72.9	24.8
****	***	***	********	*******	******

FORM B

BLUE FORCE EFFECTIVENESS (Residual M,F as of t; Cumulative C-Kill)

WPN NO.	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F
M_1	16.3	.736	20	.797	20.4	.808										
	0	0	0	0	0	0										
M_2	18.3	.745	20.3	.833	32	.8332										
	0	0	0	0	0	0										
M_3	20.3	.009	20.3	.018	24.3	.216	32.6	.224	34.1	.228	36	.230	39.1	.234		
	.982	.982	.965	.965	.583	.583	.574	.574	.566	.566	.562	.562	.554	.554		
L_3	32.6	.02	34.1	.026	36	.027	39.1	.029	39.4	.031						
	.96	.96	.948	.948	.946	.946	.942	.942	.939	.939						
G_2	32	.01														
	.98	.98														
G_3	32.6	.002	34.1	.012	36	.014										
	.996	.996	.976	.976	.968	.968										
H_1	19.2	.0396	28.3	.137	31	.16	31.1	.182								
	.925	.953	.738	.787	.707	.763	.677	.739								
H_2	23.3	.0318	26	.071	27.2	.102	30.3	.13	31.1	.153	31.1	.175	31.3	.197		
	.949	.963	.873	.917	.814	.88	.772	.847	.739	.821	.708	.796	.678	.771		

FORM C

BLUE FORCE EFFECTIVENESS (Residual M,F as of t; Cumulative C-Kill)

WPN NO.	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F
T_1	18.1 .948	.0274 .968	27.2 .856	.0768 .91	36.2 .763	.1294 .859										
T_2	18.1 .931	.0163 .957	27.2 .802	.0592 .875	36.3 .726	.091 .824	36.6	.115								
T_3	21.7 .931	.0363 .957	30.8 .802	.1063 .875	39.9 .726	.151 .824										
T_4	37.8 .225	.5 .454														
T_5	24.9 .973	.012 .982	31 .936	.032 .959	31.1 .906	.048 .94	32.4 .212	.519 .432	34.8 .103	.538 .406						
M_3	39.4 .546	.238 .546														
H_2	35.3 .537	.281 .674	36.3 .468	.327 .621	40.2 .38	.40 .536										

FORM C

RED FORCE EFFECTIVENESS (Residual M,F as of t; Cumulative C-Kill)

WPN NO.	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F
6	38.6 .47	.343 .626														
1b	24.5 .616	.248 .729														
1c	2.5 .26	.48 .477														
2a	11.1 .492	.328 .642	12 .242	.549 .412	40.5 .125	.69 .272										
2b	10 .49	.33 .64	39.3 .24	.551 .41												
2c	2.1 .266	.475 .482	9.6 .129	.65 .307												
3b	11.6 .43	.38 .588	36.4 .264	.54 .424												
3c	10.7 .46	.36 .61	12.3 .227	.57 .382	35.5 .118	.708 .249										

RED FORCE EFFECTIVENESS (Residual M,F as of t; Cumulative C-Kill)

WPN NO.	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F	(t) %M	C %F
11a	3.5 .171	.628 .345														
11b	29.1 .711	.187 .779														
11c	31.1 .932	.026 .958														

FORM D

F reflect the breakdown of system kills by weapon type, allowing for easy summation and comparison.

Since one cannot isolate, completely, two types of weapon systems for the determination of weapon exchange ratios and still have any meaning due to the homogeneous forces involved, it becomes necessary to examine the results in aggregation. Note that seldom was it the case, or realistically would it be the case, that any two types of weapon systems would only engage and attrit each other.

In line with the foregoing, a methodology for comparison of non-similar systems was needed. Realizing the limitations of such methodologies, but seeing no better alternatives, it was decided to scale the relative values of the component systems in the forces in a simple manner, not completely dissimilar from Fire Power Potential and Weapon Effectiveness Indices/Weighted Unit Values methodologies [Ref. 35 and 36], yet also not as detailed.[1] The following values or weights were judgmentally assigned to the systems:

MAW	20 points	T-62	37 points
HAW	35 points	BMP-76	30 points
M60A2	40 points	BMP-76(M)	35 points
LAW	5 points	BRDM(ATGM)	30 points
M-79	3 points	85mmATAP	28 points

[1] An excellent discussion of the limitations of such methodologies in the context of expected value and "Monte Carlo" type games is given in Reference 42, p. 2-6.

EXTRACT

RED AFV LOSSES BY BLUE ATGM TYPE (Fractional Kills)

WPN TYPE: T-62									WPN TYPE: BMP-76								
M-KILL			F-KILL			C-KILL			M-KILL			F-KILL			C-KILL		
MAW	HAW	M60A2	MAW	HAW	M60A2	MAW	HAW	M60A2	MAW	HAW	M60A2	MAW	HAW	M60A2	MAW	HAW	M60A2
.734	.54	.137	.518	.39	.175	.475	.36	.175	.829			.655			.628		
.74	.57	.51	.523	.412	.36	.48	.38	.33									
.384	.109	.508	.271	.133	.358	.248	.138	.328									
	.166	.25		.164	.23		.16	.221									
		233			.218			.21									
		25			.23			.221									
		.117			14			.141									
		.53			374			.343									

FORM F

Each fractional kill recorded was then multiplied by the appropriate system weight to give the aggregate loss to the force. Figure 28 shows the cumulative losses over time of both the RED and BLUE forces, to the point of game termination. Note that this was done just as the last M60A2 completed its second engagement. The next scheduled BLUE system firing would have been at 54.3 seconds of the battle, while numerous RED systems were scheduled to fire within the next two seconds following termination, several of which were on their second or third rounds at the same target (hit probabilities normally increasing as the firer achieves sensing of previous rounds).

In the trivial sense, BLUE disengagement before 16.3 seconds would yield the best exchange ratio. This would, of course, require the mech infantry platoon to withdraw immediately following the firing of one round from each weapon system. As of t= 16.3, the force exchange ratio is 128.5/14.7= 8.75. By the time the next RED loss is incurred (t= 24.4 sec), the exchange ratio has dropped to 137.67/42.82= 3.22. And, by game termination, the ratio is down to 181.815/113.943= 1.6, with further reductions imminent.

The weapon system loss rates have been approximated and listed in Table VI. These rates are derived from the fractional losses recorded in FORMs C through F. Of significance is the decrease in RED system loss rates after the first 15 seconds and the six-fold increase in the loss rate of M60A2s in the last 10 seconds of the game.

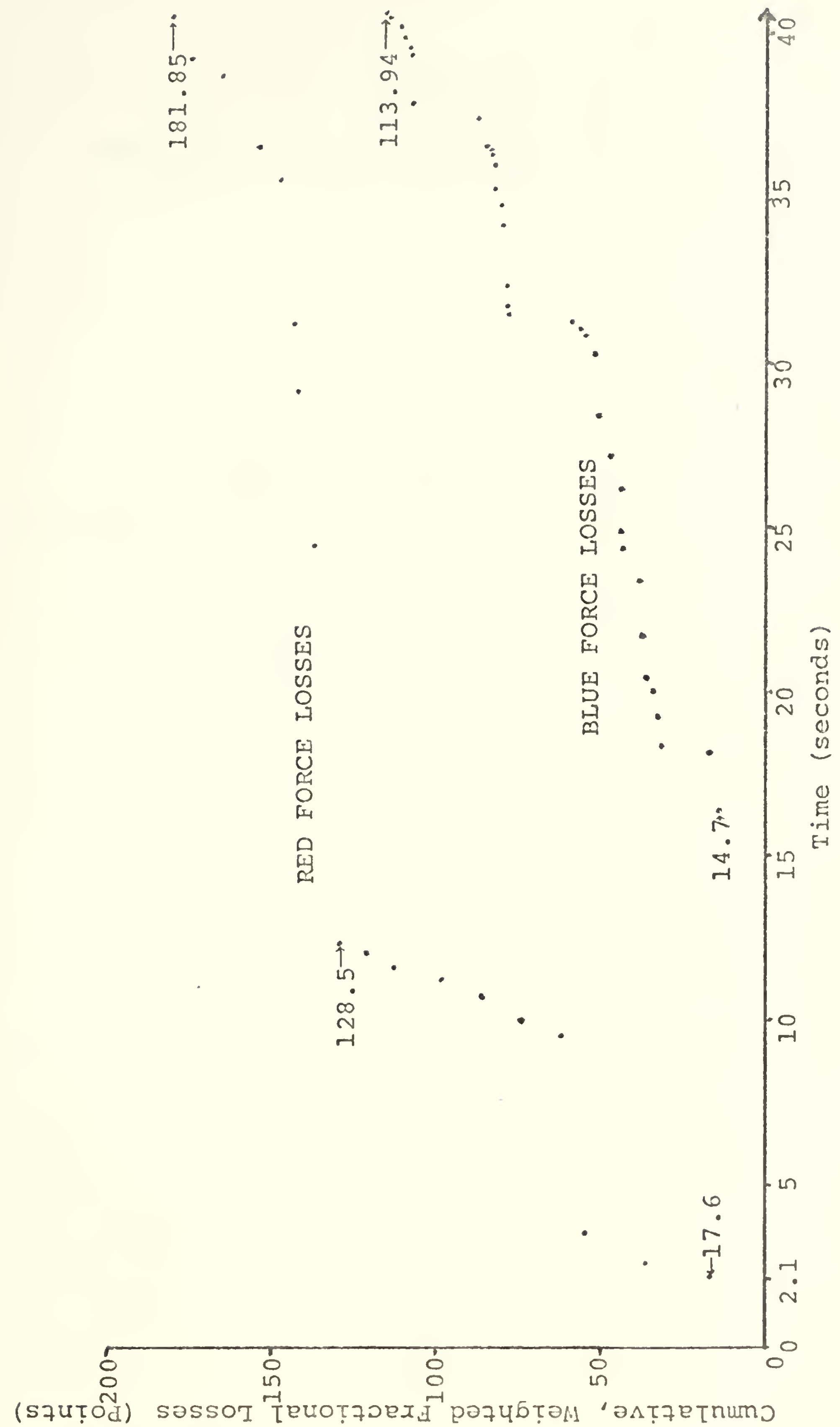

Figure 28. Cumulative, Weighted Fractional Losses

TABLE VI.

WEAPON SYSTEM FRACTIONAL LOSS RATES (KILLS/SEC)

	T-62	BMP-76	MAW	HAW	M60A2	LAW	M-79
By t= 15 sec	.198	.0419	0	0	0	0	0
By t= 30 sec	.107	.0272	.062[2]	.00797	.00575	0	0
By t= 40.5 sec[1]	.105	.021	.0468	.00946	.0356	.00078	.0006

[1]Corresponds to 1.857 kills in 30 seconds, out of a total of three weapons.

[2]The next possible T-62 or BMP-76 loss would have been at 60 seconds of the battle; whereas BLUE losses were projected to continue to occur at an increasing rate due to the entrance of more RED systems into the bat-le (85 mm ATAPs).

The initial conclusion for this particular scenario would be to have the mech infantry platoon begin to withdraw after all systems have fired one round each. And, to either position the HAW and M60A2 at initially greater ranges, or break contact after the first rounds have impacted. Further examination of Figure 28, in conjunction with the TIME-HISTORY forms reveals an interesting point: the only RED systems to achieve significant kills on the BLUE ATGM systems, with the exception of the MAW losses, are the BMP-76s armed with the SAGGER ATGM. These two alone counted, with one missile apiece, for 38. 85 points of BLUE force losses. Since these were assumed only capable of firing one missile per engagement, due to the exposure required to mount a new missile on the main gun tube during a fire-fight, and the RED AFV fire was otherwise not that significant; it appears as though the first priority for BLUE ATGM systems should be the overwatching RED ATGMs. This would then give the BLUE systems greater flexibility in engaging the tanks. (Note that removal the effect of the RED ATGMs and the high MAW losses, assuming an earlier infantry withdrawal, increases the exchange ratio to 4:1.

LIST OF REFERENCES

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As a first step in the testing of the feasibility of the FORCE-ORIENTED DEFENSE as a viable tactic for countering the large force imbalance in Western Europe, a small-unit, base-case scenario is quantitatively examined through the medium of a manual war game. A "Monte Carlo" type manual game was developed and used to refine model logic for a subsequent investigation with an expected-value manual game. This work generates the basis for a possible high resolution simulation of the FORCE-ORIENTED DEFENSE.

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20.
To satisfy secondary objectives of the study, fractional kills were tabulated to determine first approximations of armor/antiarmor force exchange ratios and weapon system fractional loss rates. The specific scenario involved a reinforced mechanized infantry platoon ambushing the first echelon units of a tank-reinforced motorized rifle battalion.

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The force-oriented defense: an expected-value approach.